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All communications should be addressed to the Editor.

No. 122. FEBRUARY, 1921. VOL. XXV.

Notices of the Royal Aëronautical Society.

Election of Members.

The following members were elected in the various grades as shown at a Council meeting held on January 25th, 1921:—

Associate Fellows.—Captain E. E. Aldrin, U.S. Air Service, Wing-Commander E. F. Briggs, D.S.O., O.B.E., Flight-Lieutenant F. L. C. Butcher, S. Payne, Esq., M.I.N.A., Hon. R.C.N.C., W. P. Rogers, Esq., A. J. Spencer, Esq., A.M.I.Mech.E., E. P. Warner, Esq., R. P. Wilson, Esq., C.B.E., M.Inst.C.E., M.I.E.E.

Students.—Captain W. C. Cooper, H. A. Dalton, Esq., J. G. Edenborough, Esq., F. A. Kerry, Esq., G. E. Page, Esq., A. P. Rowe, Esq., Flying Officer A. V. Shewell.

Members.—H. A. Crook, Esq., J. J. Holt, Esq., H.H. the Maharaj Rana of Jhalawar, Squadron Leader H. R. Nicholl, O.B.E.

Associate Members.—L. K. Forbes, Flying Officer F. L. Hopps, A.F.C.

Foreign Members.—J. McAllister Allan, Esq., Lieut. R. Arisaka, I.J.N., L. Mapelli de Pietro, Esq., Lieut.-Eng. H. N. Pantolini, Arg. Navy, Lt. Commander Louis Sablé, French Air Attaché.

Lectures.

Members are reminded that invitation cards for lectures which are held at the Royal Society of Arts, John Street, Adelphi, are no longer circulated to members; the only notification of lectures or special arrangements being, save in exceptional cases, contained in the Weekly Notices in the Press and notices in the Journal.

The lecture arrangements for the remainder of the present Session are as follows:—

Feb. 3rd, 5.30 p.m.—Major G. Dobson, "The Use of Meteorology to Aviation and Vice-Versa."
Wing Commander H. W. S. Outram, Assoc. Fellow, "Ground Engineering."
Chairman: G. C. Simpson, Esq., C.B.E., D.Sc., F.R.S., Director of the Meteorological Office.

Feb. 17th, 5.30 p.m.—F. Handley Page, Fellow, "The Handley Page Wing."

March 3rd, 5.0 p.m.—J. W. W. Dyer, "Airship Fabrics."
Major T. Orde-Lees, A.F.C., "Parachutes."
Chairman: Air Commodore E. M. Maitland, C.M.G., D.S.O., A.F.C.

March 17th, 5.30 p.m.—Capt. D. Nicholson, Associate Fellow, "Flying Boat Construction."

Scottish Branch.

It is regretted that the title of the newly-formed discussion society in connection with the Scottish Branch was incorrectly given in the last issue. The title should read, "The ex-Airmen's and Students' Section of the Royal Aëronautical Society (Scottish Branch)." The Honorary Secretary is Mr. C. R. Catesby, "Highfield," Croxley Green, Herts.

Committees.

For the information of members it may be stated that the Council, Candidates' Qualifications Committee, and Lectures and Publications Committee meet monthly at the Society's Offices in the afternoon of the third Tuesday in each month. Other committees meet as and when required.

Technical Terms Committee.

It has been arranged with the British Engineering Standards Association that the revision of the "Glossary of Aeronautical Terms," published by the Society in 1919, shall be continued under the auspices of the Association. The Technical Terms Committee of the Society, which also acted as Aircraft Sub-Committee No. 1 (Nomenclature) of the B.E.S.A., has been placed at the disposal of the Association for this purpose.

Revision of Rules.

The consideration of the Secretary's draft amendments to the rules was considered at the January Council meeting and will be completed at the next meeting, on February 15th. They will then be brought before the Annual General Meeting for confirmation.

Membership Card.

The design of a card of membership for issue to each member was approved by the Council at their January meeting, and this will shortly be issued.

Library.

The following books have been received during the month and placed in the library:—"The Theory of Direct Current Dynamos and Motors," by John Case, M.A., A.F.R.Aë.S.; Meteorological Pamphlets presented by the Smithsonian Institution; Official Year Book of Scientific and Learned Societies, 1920; "Rendiconti Dell'Istituto Sperimentale Aeronautico di Roma," September, 1920; "Clouds," by George A. Clarke, F.R.P.S., F.R.Met.Soc.

Arrangements for the Month.

Feb. 3rd,	5.30 p.m.	*Lectures.*—"The Uses of Meteorology to Aviation and Vice-Versa," by Major G. Dobson. "Ground Engineering," by Wing Comdr. H. W. S. Outram. *Chairman*: G. C. Simpson, Esq., C.B.E., D.Sc., F.R.S.
Feb. 15th,	4.0 p.m.	Lectures and Publications Committee.
	4.30 p.m.	Candidates' Qualifications Committee.
	5.0 p.m.	Council.
Feb. 17th,	5.30 p.m.	*Lecture.*—"The Handley Page Wing," by Mr. F. Handley Page.

Lord Invernairn of Strathnairn.

Members will no doubt wish to join in congratulating Sir William Beardmore, Chairman of the Scottish Branch of the Society, on his elevation to the peerage. It is understood that he has chosen as his title "Lord Invernairn of Strathnairn."

W. Lockwood Marsh, *Secretary.*

Synopsis for Paper on Parachutes to be read before the

ROYAL AERONAUTICAL SOCIETY,

BY

MAJOR T. ORDE LEES, A.F.C., O.B.E.,

3rd March, 1921.

Title—

REDUCING LOSS OF LIFE IN AIR-WRECKS.

Observation that parachutes have only recently received scientific consideration.

Pros and Cons of Parachutes.

Statistics of lives saved by parachutes.
The controversy as to their practicability on aeroplanes.
The British view.
The German data.
Objections to parachutes on aeroplanes.
Statistics of effect on performance of aeroplane.
Estimate of men who jumped from burning machines.
Authentic cases where parachutes could have saved life.
Parachutes useless in the majority of accidents.
Estimate of percentage who could be saved from aeroplanes.
The official adoption of parachutes on aeroplanes by the R.A.F.

Parachutes and Civil Aviation.

Civil aviation must follow suit sooner or later.
Objections to fitting parachutes to civil aircraft.
Parachutes and the pressure of public opinion.
Recent crashes in which parachutes might have saved lives.

The Big Machine Problem.

The baffling problem of the multi-passenger machine.
Existing solutions.

Some Inventions.

Useless parachute inventions.
Common parachute fallacies.
American parachute patents.
Inadequate parachutes.
Parachute-flying-machine ideas.

History.

The investigations of Leonardo da Vinci and Montgolfier.
Early parachutists. (Very lightly touched on.)
Cocking's experiment. (Ditto ditto.)
The parachuting of bursting balloons.

Various Types of Parachutes.

The parachute machines of De Groof and Le Tour.
Why aeroplanes cannot act as parachutes. An exception.
Falling speeds.
Minimum parachute dimensions.
A parachute overcoat which killed its inventor.

Various Types of Parachutes.

The various existing systems of parachutes. Pros and cons.
Extraction parachutes.
Pégouds wonderful experiment.
The first man to jump from an aeroplane.

Action of Parachutes.

The action of a parachute launched from an aeroplane.
The effect of forward momentum.
Terminal velocity.
Variable speed parachutes and the reason for them.
Dirigibility.
Positive extension.
Positive opening; its vital necessity.
Tangle-proofness.
Either side delivery.
Any position parachutes.
Dragging.
Quick releases.
Demonstration drops.

Can Parachutes Help to Save Civil Aviation?

Inability of air passengers to use parachutes.
The overwhelming incentive of fire.
Statistics of civil aviation fatalities.
Comparison of air fatalities with railway and marine fatalities.
The City man's view towards air transport.
The imperative need of rendering air-travel safer.
The parachute's part in the future of aviation.

PROCEEDINGS.

FIFTH MEETING, 56th SESSION.

The Fifth Meeting of the Fifty-Sixth Session was held on Thursday, December 2nd, 1920, in the Hall of the Royal Society of Arts, London, Air Marshal Sir Hugh M. Trenchard presiding.

The CHAIRMAN said it was a great honour to be asked to preside at the reading of these particular papers. He need hardly say how interested he was or that he had been reading every scrap of information he could get both on airship mooring and airship piloting. It was not necessary for him to introduce Major Scott. He was well known as the pilot of the R.34 which flew to America. He would ask him at once to read his paper.

Major G. H. SCOTT, C.B.E., A.F.C., then delivered the following lecture:—

AIRSHIP PILOTING.

I feel it a great honour to have the privilege of addressing the members of the Royal Aeronautical Society on the subject of Airship Piloting, especially in view of the interest you have taken in furthering and generally assisting in the development of all types of aircraft.

Although the airship has hitherto not occupied the thought and brains of Aeronautical Engineers to the same extent as the aeroplane and seaplane, I feel sure the confidence and support of the Society will lead to a more general and scientific interest being taken in lighter-than-air craft, which is bound to result in more rapid progress in the near future.

I hope the discussion to follow will provide the foundation for solving some of the problems that will have to be faced, when piloting the airships over routes to various parts of the world, where totally different atmospheric conditions are likely to be encountered. Once these problems are solved, I feel that the future of the airship as a mode of fast long-distance transport is assured.

In the early days of sea-going ships, the captain of the ship worked the helm, and by his own personal observation and skill at the helm, navigated his ship in unknown seas, but his progress was slow and the distance covered comparatively small.

As the size of the ship increased, the captain handed over the helm to one of his men, and turned his attention to the navigation and the general working of his ship. As the ship grew bigger still, and the speed and range increased, he relegated more duties to his junior officers and turned his attention to the control and co-ordination of the whole.

It is the same with the airship. In the early days when airships were small, the pilot himself worked the controls, but as the size increased he turned his whole attention to the navigation and general piloting of his ship, his crew working the controls. Thus the captain of the large airship of the future, although having an intimate knowledge of the detail working of the airship, will merely control and

direct, and his chief study will be the weather, and the best method of using it, to make a quick, safe passage.

It is this side of piloting that I will chiefly consider in this Paper, and will deal with it under four heads—

(*a*) Aerostatics of Airships.
(*b*) Aerodynamics of Airships.
(*c*) Weather with regard to Airships.
(*d*) Navigation.

AEROSTATICS.

Before discussing the piloting of airships, it is necessary first to appreciate the statical conditions which govern their performance.

(*a*) Lift of Hydrogen.

In modern airships the gas used to give the buoyancy or lift is hydrogen. This gas has a weight of only 1/15 the weight of an equal volume of air at the same temperature and pressure.

That is at normal temperature and normal atmospheric pressure, 1,000 cubic feet of hydrogen weighs approximately 5lbs., whereas 1,000 cubic feet of air weighs 75lbs.

So that under usual conditions pure hydrogen has a buoyancy or lift in air of between 70lbs. and 72lbs. per 1,000 cubic feet.

In practice it is impossible to obtain or maintain pure hydrogen in the airship, it is therefore necessary to know the degree of purity.

This is determined by means of a purity meter, which gives the relative density between the air and the hydrogen under test.

The relation between air and pure hydrogen is known, so that a relation can be calculated between the hydrogen tested and pure hydrogen. For convenience, it is assumed that the impurity is air, and the "purity" is expressed as the percentage by volume of hydrogen in a mixture of hydrogen and air, which would give a similar density to that of the mixture of gases tested. Thus a purity of 90 per cent. means a density corresponding to a mixture of 90 per cent. pure hydrogen and 10 per cent. pure air at the same pressure and temperature.

This figure has to be applied in calculations of the lift of hydrogen, and the true lift is obtained by multiplying the lift of pure hydrogen by its per cent. purity.

(*b*) Effect of Barometer on the Lift of Hydrogen.

As an airship has a fixed maximum volume, it is usual to deal with the lift of hydrogen for a fixed volume, 1,000 cubic feet is usually taken as the unit of volume.

With alterations of barometer, the density of the hydrogen and the density of the air displaced, and therefore the lift of the hydrogen, varies.

For the purposes of calculation, Boyle's Law is sufficiently accurate.

Thus $PV=K$, or the density is proportional to the pressure, that is, the lift of a fixed volume of hydrogen is directly proportional to the pressure of the barometer.

It is assumed that the same pressure exists inside and outside a gas bag. No correction has, therefore, to be made in the case of temperature.

(*c*) The Effect of Temperature on Lift of Hydrogen.

The density of air and hydrogen vary with temperature, and assuming a constant pressure the density varies according to Charles' Law, or the density

varies inversely as the absolute temperature, therefore the lift of hydrogen varies inversely as the absolute temperature.

Taking temperature, purity and barometric pressure, the lift of hydrogen is given by

$$L = \frac{B}{T} \times P \times K.$$

where L = Lift per unit volume of the gas.
B = Barometric pressure.
T = Absolute temperature.
P = Percentage purity of the gas.
K = Constant, depending upon the units used.

Superheating.

In the foregoing consideration of the lift of hydrogen it is assumed that the hydrogen and air are under the same pressure and temperature. In practice this is reasonably correct with regard to pressure, but with regard to temperature very big differences can be experienced.

Thus when an airship is flying through a warm sun, the temperature of the gas is raised above that of the surrounding air. This condition is termed superheating, and in British practice is measured by the number of degrees Fahrenheit between the temperature of the air and the temperature of the gas. Thus a 10° superheat means the gas is heated 10°F. above the surrounding air.

The Effect of Superheating.

If an airship contains a known quantity of hydrogen, that is, a known weight of hydrogen, and the temperature and pressure of the hydrogen are the same as that of the air displaced, then the lift of this fixed weight of hydrogen will remain constant whatever the pressure and temperature.

Thus in a rigid airship where the gas bags are not full, the ship can rise or fall, and as long as no gas is lost and no superheating takes place the lift will remain constant.

In practice a rigid airship is seldom full of hydrogen, and I will deal with the effect of superheating on an airship under this condition.

The volume of the gas in the airship depends upon the barometer and the temperature of the gas, and is given by

$$V = \frac{T_1}{B} \times K$$

where T_1 is the gas temperature.

Now this is the volume of air displaced, so that the lift of this gas is given by

$$L = \frac{B}{T_2} \times K \times V$$

where T_2 = air temperature,

$$\text{or } L = (T_1 / T_2) K.$$

Thus the lift of the gas is increased on superheating and is calculated by taking the lift without superheating and multiplying by

$$\frac{\text{the absolute temperature of the gas}}{\text{the absolute temperature of the air}}$$

Or the increase in lift due to superheating = lift without superheating multiplied by

$$\frac{\text{the degree of super-heating (}i.e.\text{, difference between gas and air)}}{\text{absolute air temperature of air.}}$$

This quantity is known as the false lift.

There is an error in the above method owing to the fact that the weight of 1,000 cubic feet of hydrogen varies with the temperature, and it is therefore not correct to assume that the lift is directly proportional to weight of air displaced. In the above the temperature of the gas is only taken into consideration to obtain the new volume of the gas.

This error is, however, comparatively small, and is therefore neglected in practice in order to simplify the calculation.

A condition occasionally arises when the gas temperature is lower than the air temperature; the decrease of lift in this case is known as latent lift.

Aerodynamics.

The study of the aerodynamics of airships is primarily a design problem, but it is so inseparably connected with piloting that I cannot neglect the subject in this Paper, especially in connection with future and larger ships.

Head Resistance.—The head resistance of airships of the same form for the same velocity varies as the (capacity) $^{2/3}$ and the lift varies as the capacity.

The per cent. total weight of the airship required for propelling machinery to give a constant speed, therefore, decreases as the size increases, or, with a constant per cent. of machinery weight, the speed of an airship increases as the (capacity) $^{1/9}$ or as the $\sqrt[9]{}$ length.

At this increased speed the range for the same per cent. weight of petrol carried is also increased, so that for ships of the same form of the same per cent. weight of machinery and the same per cent. weight of petrol carried the speed and range each vary as the (capacity) $^{1/9}$.

Dynamic Lift.—The dynamic lift of an airship may be defined as the component at right angles to the flight path of the resistance of a ship moving through the air with its centre line inclined to the path of flight.

It is the vertical component of this dynamic lift that is employed to maintain an airship at constant altitude, or to drive her up or down, when the ship is not in static equilibrium, that is, when the lift of the gas is greater or less than the weight of the ship and her cargo.

With ships of similar form this dynamic lift may be taken as proportional to the resistance for the same angle of flight, or to borrow a term from H/A, the same " attitude " of flight.

Thus if the same per cent. weight of machinery is employed the maximum dynamic lift (expressed as a percentage of the displacement) varies as (capacity) $^{8/9}$ so that practically the same degree of superheating can be dealt with.

But if a constant speed were maintained and the capacity increased, the per cent. weight of machinery would be decreased, and therefore the degree of superheating that could be dealt with without loss of gas would decrease.

In the design of large ships this fact must not be overlooked, or for large ships with a long range it may be necessary to carry so much water ballast that the advantage gained by increase in size may be nullified.

Controllability.

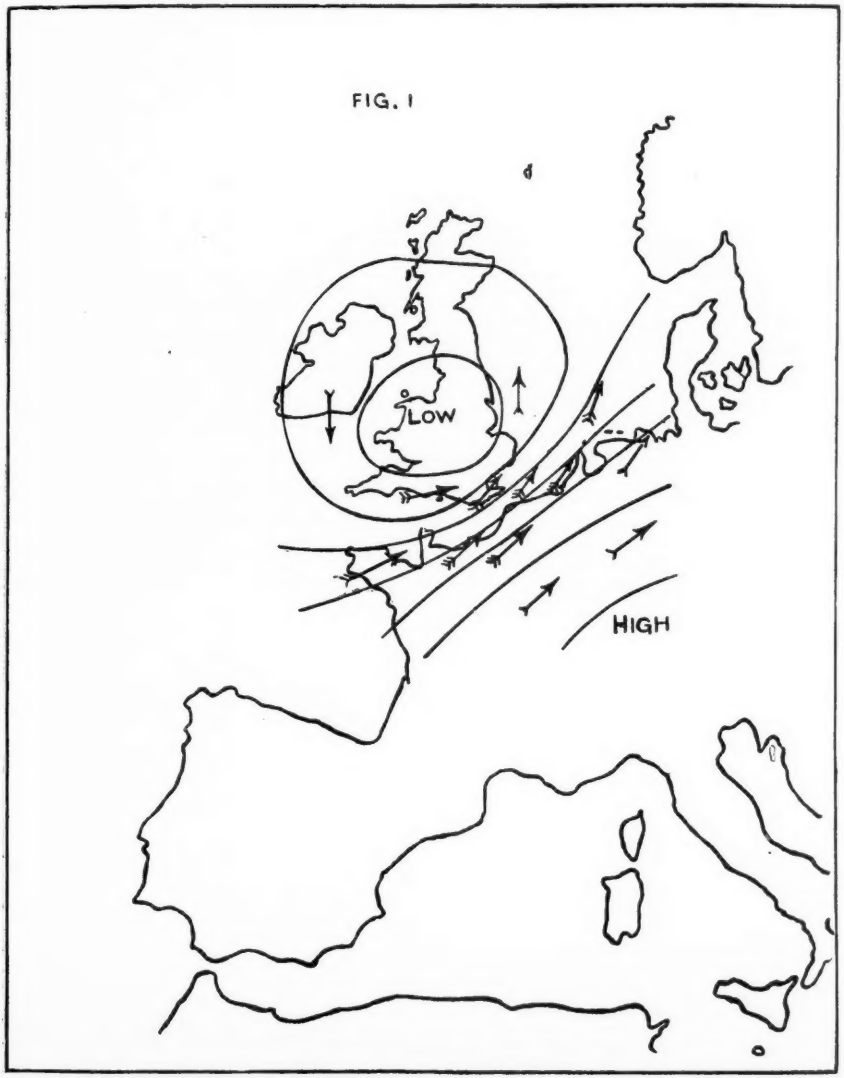
As there are so many factors that affect the controllability of an airship, I fear I cannot deal summarily with the subject.

A stream-lined airship if travelling through the air at a small angle to the axis of the ship, instead of tending to return to the direction with its centre line parallel to line of motion tends to increase this angle.

This has a marked effect on the controllability when a ship is flown " light " or " heavy."

Thus when a ship becomes light she appears to be nose heavy, and conversely when she becomes heavy she appears to be nose light.

This effect acts in favour of the pilot at certain speeds, but at high speeds, when a ship is more than a certain per cent. light or heavy, the effect becomes so



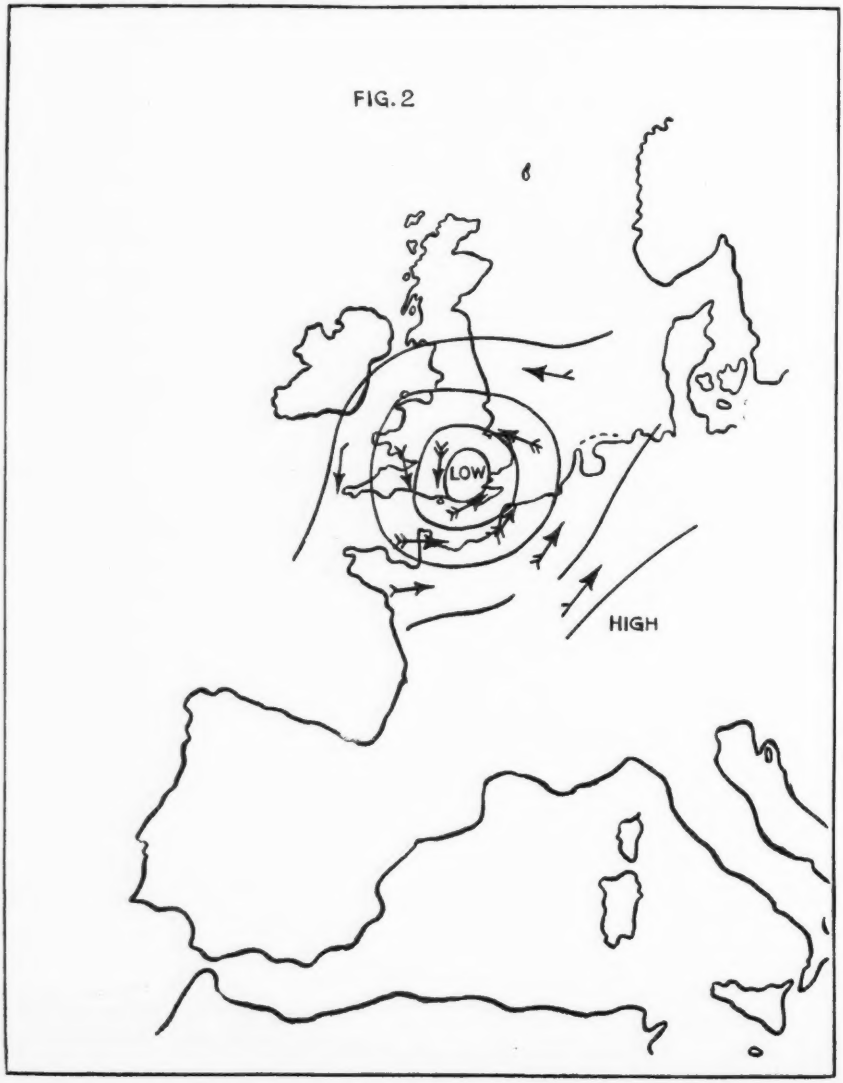
great that the elevators cannot cope with it, and the ship, if heavy, will continue to climb, or if light continue to dive.

The correction if such a case should occur is to slow down the engines.

In the event of the elevators jamming, this unstable property of a streamlined ship can be employed to pilot a ship back to her base.

The German airship pilots have experienced this effect, and in L67 the horizontal fins are placed on the hull at a permanent angle down by the tail. This allows the ship to fly very heavy, thus permitting the pilot to take his ship to a great height when raiding, allowing for the release of weight in bombs and petrol used to bring his ship to equilibrium before landing.

FIG. 2



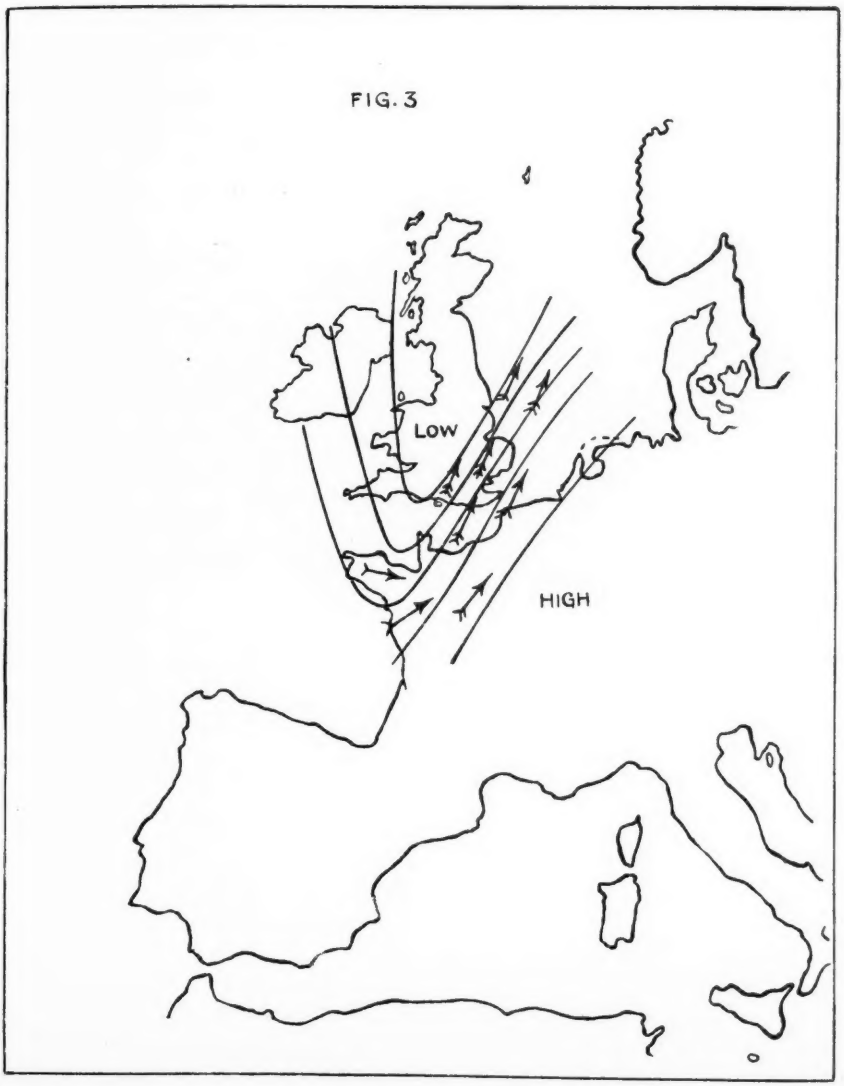
A more detailed consideration of the forces acting on a ship under this condition is given in Appendix *A*.

Weather.

There is a general idea that an airship is a fine weather craft. This is only partially correct.

An airship up to the present time has been under the disadvantage of having to leave and enter its shed at the beginning and end of each flight, and as there

FIG. 3



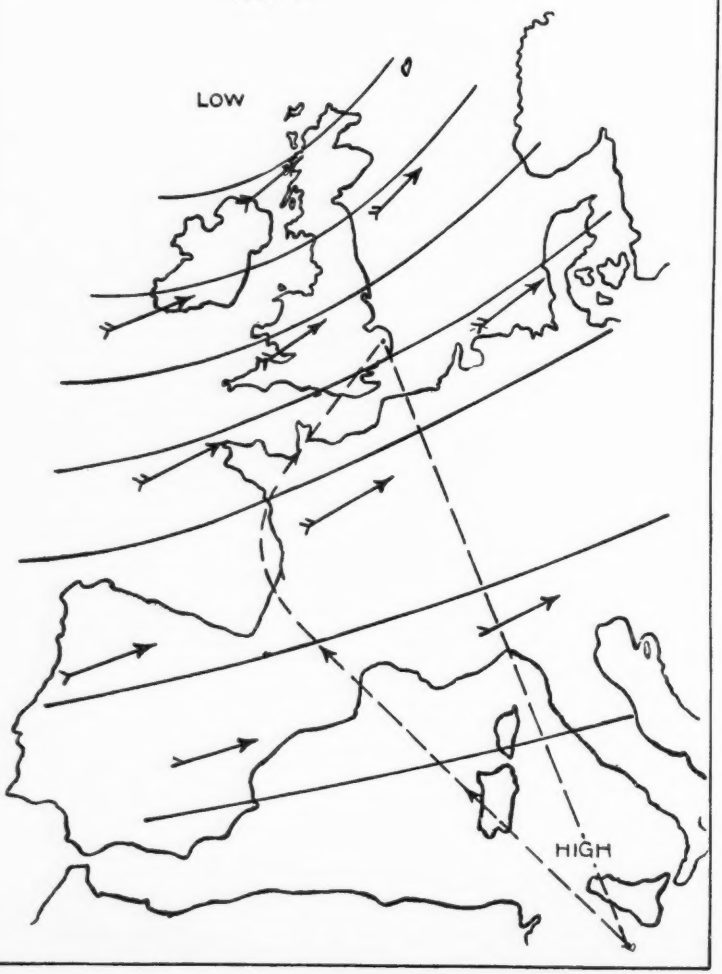
is difficulty in handling a ship in and out of her shed in strong winds, this has limited the application of the airship in the past to fine or moderate weather.

An airship once in the air is not a fine weather craft, and a large ship with a good range and speed need not fear any type of weather.

Experiments are at present in hand which will allow of an airship landing or leaving a mooring mast or tower in strong winds, and when these experiments are completed there is little doubt that an airship will be almost as independent of the weather as sea-going passenger liners.

I will divide up weather into groups and discuss each separately.

FIG. 4.

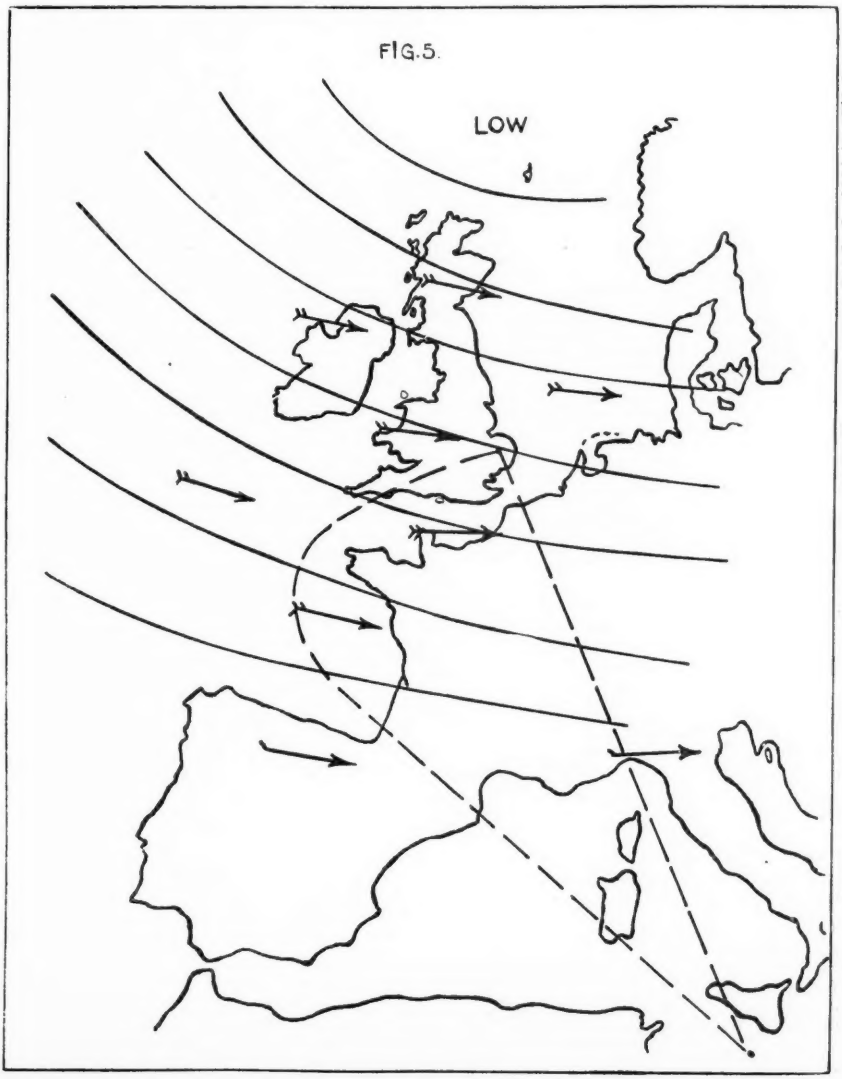


(*a*) **Wind.**

Strong winds in this country and in the Atlantic are caused by depressions or cyclones. These cyclones are approximately circular in form with the wind blowing round them in a counter clockwise direction with a slight bearing towards the centre or low pressure zone.

They vary very considerably in size, and may cover half the Atlantic or be only 200 miles in diameter. The larger the depression the longer warning we have of its approach, and therefore the easier it is to avoid or utilise.

Also, except in rare cases, a very large depression is only associated with very high winds, over a comparatively small area.



The strength of the wind is largely dependent upon the distance apart of the isobars. The shorter this distance the stronger the wind. It is obvious, therefore, that where the winds are strong and the isobars close together the area covered must be small.

Thus a pilot, on meeting a strong wind, turns broadside on to the wind, and in a very short time he will be through the bad zone and in a light or favourable wind. It will be seen that the time taken for the ship to cross the bad weather zone does not depend upon the strength of the wind but upon the speed of the ship, also that the amount the ship drifts out of its course depends, on the other hand, on the time taken and the speed of the wind. It is therefore necessary that the ship should have a good turn of speed, so as not to be driven too far out of her course.

Except in very rare circumstances, such as when the base at which the pilot wishes to land is in the bad weather zone, a pilot should never beat directly into a strong wind, and even in the above case it often pays to lie off for a few hours, as the movement of the centre of the depression will move the area of strong wind away from the base.

It is owing to this movement of the centre of a depression that, except in exceptional circumstances, a very strong wind does not blow for very long in one place. I have pointed out above the general method of dealing with strong winds, and endeavoured to explain that they are not a serious obstacle to the airship and should not interfere much with schedule flights.

A much more difficult wind for the airship pilot to deal with is a head or beam wind of from 20 to 30 miles per hour, as this may blow over a comparatively large area and for long periods.

In order to deal with this wind, good meteorological reports must be at the pilot's disposal, and he must vary his course sometimes 12 to 24 hours ahead in order to circumvent such a wind. As an example, the pilot is flying from Malta to Norfolk, there is a large depression centred N.W. of Scotland, giving a westerly and south-westerly wind over the South of England and North of France. If the pilot endeavoured to make good a direct course from Malta to England he would be obliged to edge up into a 30-mile broadside wind over several hundred miles, and the time taken for the journey would be greatly increased.

If, however, the pilot was supplied with good meteorological information he would set his course so as to pass out into the Bay of Biscay, just north of the Pyrenees, and when he encountered westerly winds of increasing force he would turn north at right angles to the wind and use the drift to make his base. Thus during no part of his journey would he be heading into a wind, and although the course taken is somewhat longer than the direct route, the time taken will be very little in excess of the still air time, and with a reasonable amount of spare engine power the airship could still make its scheduled time on the journey.

Necessity of knowing true height above surface.—In order to use the meteorological information to the best advantage, the pilot should be in a position to read the ground barometric pressure at any moment, so as to know whether he is approaching the high pressure or low pressure zones, or flying parallel to the isobars, and thus estimate the rate of movement of the depression.

This is impossible at present, as there is no known method by which a pilot can measure with accuracy or regularity his true height above the surface. Thus the barometric pressure measured in the ship gives no accurate measurement of the surface barometer.

Some instrument or method of overcoming this difficulty is most urgently needed.

Effect of height on wind velocities.—At the present time there is not a great deal of data regarding the variation of wind velocities and direction with height. Such data as is available chiefly deals with anti-cyclonic conditions when the air

is clear and a pilot balloon can be sent to a great height. This is the fine weather condition, when the need for alteration of altitude to avoid bad winds is rarely necessary.

The cyclonic conditions over the British Isles are nearly always associated with comparatively low heavy clouds, when it is impossible to follow a pilot balloon to any height, and it is under these conditions that further data is required.

My general experience has been that westerly winds increase with height, whereas easterly winds tend to decrease, both tending to turn anti-clockwise.

We, however, had an interesting experience on R34 on the trans-Atlantic flight which would tend to qualify the above statement.

When within 800 miles of Newfoundland, R34 encountered a shallow depression of about 600 miles diameter and giving a ground wind of about 45 to 50 miles per hour, with low clouds and driving rain. After several hours, during which time we were being driven north, it was decided to climb through the clouds and try to check our position by a sun sight with a cloud horizon. At 5,000 feet we passed clean out of the top of the depression, and into a light westerly wind. This was calculated by cloud drift, and later checked by the time and position we passed over the Newfoundland coast. Thus in this case, by rising a few thousand feet, we avoided the strong southerly wind which was blowing at the surface.

I very much doubt if in the ordinary case over land the comparatively low height to which R34 ascended would have helped us very much, but it rather pointed to the fact that over a large expanse of water like the Atlantic many depressions do not rise to the high altitudes generally supposed.

In this case, as in many other cases, the heaviest clouds were situated where the wind change took place.

Permanent Winds.—The advent of the steam ships has to a large extent reduced the value of the permanent winds of the world, but these winds played a great part in the early development of the Mercantile Marine, and are destined to play a great part in the development of aerial commerce.

It was due to the position of Spain, situated almost in the trade winds, that gave her such an advantage in the development of Central and South America, and it is interesting to note that all the Spanish possessions in America were situated so as to use the trade winds.

The permanent winds of the world may be divided into two classes: (1) The easterly or trade wind, which blows north and south of the equator in easterly direction and towards the equator; (2) The westerly drifts, which are found in the Arctic and temperate zones.

The principal westerly drifts are in the North Atlantic, where they are modified and interrupted by the cyclones which pass over this region, and the great westerly drift round the Antarctic Continent which affects the southern part of the South Atlantic, the Indian Ocean and the South Pacific Ocean.

There are also many smaller permanent winds and also seasonal winds, such as the Monsoons.

In considering the future airship routes of the world, these winds must be taken into account.

Examining the probable routes to Australia and South America, it will be seen that the tendency is for the westerly journey to be made near the equator, using the trade winds, whereas the easterly journeys are always farther from the equator so as to use the westerly drifts. The gain in speed and regularity is so great that even with greatly increased speed it is still advisable, where economic conditions allow, to choose a route that will employ these winds.

Height of Trade Winds.—Although the area of the trade winds is well-known and well-defined, very little is known except of the surface winds, and it is very important that further investigations should be carried out to find to what height these winds extend and if there is a return westerly wind at any reasonable height.

Over the West Indies the greatest force is found at between 2,000 and 3,000 feet, and a falling off in wind velocity occurs above this. It is probable that well clear of land the greatest velocity is even lower, and comparative calm or a return or trade reversal wind will be encountered at no great height. If this is found to be the case the commercial value of these trade winds will be enormously increased.

Convectional Winds.—These winds, compared with the permanent winds, are very local; they are met with all over the world, and are due to the uneven heating of the earth's surface. Land and sea breezes are of this class, also the permanent northerly wind over Egypt. Convectional winds are met with in the Atlantic where the gulf stream and Labrador currents travel parallel to each other. They are of distinct use to the pilot who understands them and knows how to make use of them, but owing to their small area they are, of course, of small importance compared to the permanent winds.

(*b*) **Temperature.**

I have already described superheating under aerostatics and aerodynamics, but have given no indication as to the degree that may be expected or best method of reducing this effect.

In most cases superheating is due to direct heat from the sun, and is therefore likely to be much more serious near the equator, but until flights are carried out in tropical or semi-tropical climates it is difficult to estimate the degree that we may expect.

The effect of the sun is to raise the temperature of the gas, and the maximum temperature obtained in still air depends upon the sun's intensity, without respect to the surrounding air. The degree of superheating, however, is the difference between this temperature and the temperature of the surrounding air, so that the higher the temperature of the surrounding air the lower the degree of superheating for any known sun's intensity.

The sun's intensity tends to increase with height whereas the air temperature generally decreases, so that the best method of reducing superheating is to fly low.

The greater the degree of superheating or difference of temperature between the gas and the air, the more efficient the cooling due to the ship's motion through the air, but the result will still be a greater degree of superheating with height.

The type of outer cover is also a big factor in superheating; the better the outer cover the greater the amount of sun's rays reflected, and therefore the less heat absorbed which has to be dissipated to the air by the motion of the ship, and therefore the lower the temperature of the gas.

Speed also plays a part, as the higher the speed the more easily is heat carried away by the air; so that the best method under most conditions to reduce excessive superheating is to go fast and fly low.

Inversion of Temperature.

There are certain conditions when the temperature of the air on the ground is lower than the temperature at a height. This occurs at certain times of the day in many parts of the world, and when such a condition is encountered the pilot will only increase his superheating by flying low.

R.34 encountered a very marked example of this over the ice fields off Newfoundland. The lower air was cooled to below freezing by the ice and the sun was very powerful owing to the clearness of the air above.

The maximum superheating on this occasion was as much as 40deg.F. at 4,000 feet, which is the greatest I have yet encountered.

An inversion of temperature may cause trouble when leaving the ground if unexpected, as if a pilot ballasts up his ship just slightly light on the ground he will find it practically impossible to force his way up into the hot air above, and as this inversion is often found at only 200 to 300 feet, there is a serious danger of hitting some obstacle.

This condition is more generally encountered in the tropics.

Method of Superheating to Reduce Gas Consumption.

Superheating is not always a drawback, as if a ship leaves the ground during the heat of the day when highly superheated, and lands again at night with no superheating, the loss of lift due to the false lift which disappears after sunset will partially or wholly counterbalance the weight of petrol consumed, so that little or no gas need be expended.

Electric Storms.

Electric storms are the airship's greatest danger. There is not a very serious danger from lightning, as on at least two occasions German airships have been struck without causing serious damage.

The chief dangers from electric storms lie in the very serious bumps and eddies that accompany them; these can be extremely violent and very seriously stress the structure of the airship.

The electric storms are generally confined to certain areas and certain periods of the year; also it has been my experience that an electric or thunderstorm follows a very definite track, and there are many places both in England and abroad where a thunderstorm is unknown; it may pass within a few miles but never over that particular spot.

It should therefore be possible to chart the disturbed areas and tracks of storms, showing the areas immune from storms. If such a chart was available, and reasonable warnings are given, it would be extremely bad pilotage for a captain of an airship to allow his ship to be overtaken by a thunderstorm.

My experience has also been that thunderstorms do not travel out to sea; they may follow a line of islands, or cross from one mass of land to another, but they always tend to hug the coast; I have also never met a thunderstorm at sea. I am, of course, speaking entirely of the temperate zone as I have no experience of the tropical thunderstorm.

It is of particular importance that data on this subject should be collected.

Instrument for detecting direction of a thunderstorm.—This instrument would be of very great value to an airship pilot, as for many years to come he will of necessity be flying over regions only partially charted, and the fact of knowing from which direction the atmospherics are coming will enable him to avoid disturbances.

Electric Disturbances at Great Height.

There is very little doubt that very violent thunder or electric storms take place at high altitudes, of which there is no indication on the ground.

R.33 recently encountered such a storm, and neither the wireless nor meteorological instruments at Howden gave any indication of the disturbance; reduction in height would be a method of avoiding such a disturbance.

In the same way under certain conditions when violent atmospherics are encountered at low altitudes, higher altitudes may be free from disturbance.

Clouds and Fog.

Neither clouds nor fog seriously inconvenience an airship. With present navigational facilities a good course can be maintained without seeing the ground, and the stability of the airship prevents any inconvenience in flying.

The effect of heavy rain is to make an airship become heavy, but this can generally be avoided by alteration of height.

In a cloud that does not reach to the surface of the earth the dryest part is the bottom, so that if a ship is becoming heavy flying through clouds, the correct method is to reduce height, provided it is inconvenient to fly above them.

When flying over clouds it will generally be found that on the uneven surface the highest points have a tendency to lean over in one direction.

This gives an indication of the relative velocity and direction of the wind above and below the cloud bank. If the top surface is smooth and flat very little difference in wind need be expected.

The use of clouds for weather forecasting is a very big subject, and outside the subject dealt with in this Paper. It is, however, a most important study for the airship pilot, and should be given a more important position than it holds at present.

The observer on the ground is often handicapped by the presence of low clouds which have slight significance for weather forecasting, and is unable to get a good view of the higher and important cloud formation. The observer in the air has not this handicap as he can fly above the low clouds and get an uninterrupted view.

Snow.

The chief danger from snow is that it may, under certain conditions, cake on the bow of the ship and drive it down owing to its weight.

It is, however, only the soft wet snow that tends to cake, and by rising 1,000 feet or more dry snow will be encountered which will not tend to collect on the ship. There is an electric effect felt from flying through dry snow, and the ship is apt to become highly charged, so that it is always advisable to pull up the aerial under these conditions.

NAVIGATION.

(*a*) **Dead Reckoning.**

This method can only be used when the surface of the earth is in sight, and although in many parts of the world this may be a common condition, over the North Atlantic and the British Isles it is the exception and other methods must be employed.

Over land.—When flying over a well-surveyed civilised country it is merely a question of map reading. If, however, the country is only partially surveyed, the same methods will have to be employed as when flying over the sea.

Over the sea.—The chief instrument used is the Drift Indicator. In this instrument hair lines on glass or thin wires are arranged in a horizontal plane parallel to the earth's surface, and while observing through an eyepiece, it is possible for the pilot to move the glass or wire round until the objects on the earth's surface appear to travel along the lines in the instrument; the angle is then read off between the line of flight of the ship and the line made by the wires. This angle is known as the drift angle, and is given in degrees port or starboard. The direction of flight of the ship is known so that the direction the ship is making good over the ground can be calculated.

On some of these instruments it is possible to measure the speed made good over the ground by timing the passage of an object between horizontal lines at right angles to the drift lines, but in order to obtain a correct estimate of ground

speed it is necessary to know the true height above the ground. The barometer in the ship does not necessarily give this owing to a possible alteration of barometric pressure at sea level or variation in height of land that the ship is flying over, so that this is an additional reason for the design of some instrument to give this true height of the ship above the earth's surface.

In the case where the sun is nearly overhead and the angle of drift is small, another method of obtaining ground speed is to time the shadow past any fixed object.

A true height above sea level can also be obtained by measuring the angle subtended by the length of the shadow with a sextant, the length of the shadow being known.

There is another method that can be employed where the height of the ship above the ground is not a factor.

A drift angle is taken, first with the ship flying on her true course and then with her flying at approximately 45 degrees either side of this course.

With the construction shown the true wind direction and strength is found and the speed made good over the ground can be calculated.

This method necessitates taking the ship off her course, but if she is flown about the same time on both legs of the triangle little time is wasted, and any error in the ship's position can be calculated and allowed for after the wind direction and strength has been determined.

(*b*) Sun and Star Sights.

The only difference between using this method on surface craft and airships is the very large difference in the height of eye, and therefore distance of the horizon; this often makes it difficult to obtain a good sea horizon, so that a cloud horizon or mist horizon has often to be used. These horizons are on the whole satisfactory, but owing to the irregularity of the cloud formation great accuracy cannot be expected, but an average degree of accuracy of about 10 to 15 miles can be obtained, which for most cases is sufficient.

The height of eye above the cloud or mist is obtained by descending to the top of the mist or cloud surface and then rising a definite distance above it. It is advisable to rise a considerable distance above the cloud or mist surface as this reduces the error due to irregularities.

The types of instrument employed are :—

1. Naval Pattern 7in. Sextant.

This type of sextant is most suitable for taking observations to a natural or cloud horizon. It is necessary, however, that the mean of several sights should be obtained, having rejected those which are obviously in error. The disadvantage of this type of sextant, however, is its weight and head resistance owing to its size. For this reason a naval pattern 4in. sextant has considerable advantages for similar observations.

Observations to sea horizon with either of these sextants give fairly good results, but are entirely dependent upon the clearness of the sea horizon and a correct estimation of height for dip allowance. Double altitude observations of the reflection of the object on still water have given very good results, but it is obvious that instances of this kind are not common and that observations to reflection on the surface of the sea, even under best conditions, would not be reliable.

During a 1,100-mile flight round England carried out recently, the performance of various navigation instruments was investigated. The errors in position lines obtained from observations with the 4in. N.P. sextant by observing the reflected

image in a pool was 5 miles and 6½ miles, the result being worked on a single observation in each case.

On other occasions, however, when there was less time to make the observation owing to the smallness of the pool, the errors were considerably greater. It is clear, therefore, that this is not a method which can be of general use.

2. The R.A.E. Bubble Sextant.

This type of instrument is a complete departure from the pattern of the Naval Sextant, and is especially adapted for use in the air. Its main features are a bubble horizon with a combined index and object glass, which is set at different angles by the revolution of a spiral cam, to which is attached a scale graduated in degrees.

The bubble chamber contains alcohol and has a flexible wall which may be extended or compressed by means of a screw, so enlarging or diminishing the alcohol vapour bubble. The bubble itself is formed under a concaved glass roof which may be illuminated at night by a lamp of variable luminosity. The image of the bubble is reflected by means of a prism on to the object glass, which simply consists of a plain sheet of glass which acts as a semi-reflector. The image of the celestial object is seen reflected on this same glass surface, and is brought into coincidence with the bubble by revolving the spiral cam, the angle of inclination of the glass being registered on the scale.

This type of sextant obviously does away with the necessity of a natural horizon, whether land, sea or cloud. In common with all artificial horizons when used in aircraft, however, the level is subject to error due to the acceleration of the machine acting on the bubble.

Semi-diameter calculations are also eliminated by the use of this sextant.

One difficulty with this instrument is to obtain an index error. This, however, can be obtained by suspending a mirror vertically and taking the reading of the image of the observer's eye in the mirror.

On the Cairo to Cape flight the errors in the position lines, from observations with this type of sextant, were from 4 to 12 miles.

During a recent extended flight the maximum error in position line was as much as 34 miles obtained from the mean of six observations, and the minimum error was five miles from the mean of four observations. The variation was due to the difference in atmospheric conditions on different days, the bad results being obtained on extremely bumpy days.

These tests were carried out in an aeroplane, and better results may be expected in an airship owing to the slower movement.

Many other designs of sextants involving the use of bubble horizons and reflected back and front horizons have been used, but their low degree of accuracy and disadvantages in design have led to their elimination.

Instruments for the rapid solution of the spherical triangle by means of plotted curves and graphical representation of formulæ have been tried, amongst which may be mentioned the Baker Navigating Machine, the Veater Diagram and the d'Ocagne Nonogram. These, however, have not given the high degree of accuracy desired under all circumstances, but were admirable as a stop gap.

The Bygrave Slide Rule has given remarkably good results and is rapid in solution. It consists of two cylindrical concentric scales—one a cosine scale and the other a tangent scale, and by dividing the spherical triangle into two right-angled triangles the zenith distance and azimuth can be computed.

Directional Wireless.

The use of directional wireless will no doubt play an important part in the

navigation of airships in the future, and even at the present time forms a means of checking a D.R. position or a fix, but owing to the atmospheric errors that cannot be calculated or allowed for, and the difficulty of always obtaining a good fix, it should only be looked upon as an important aid and not a substitute for other forms of navigation. A good pilot should use every method available to check his position, however accurate any one of them may appear to be.

Conclusion.

I have endeavoured to put before you the difficulties encountered in airship piloting, and the methods employed to overcome these difficulties. I have tried to show you that an airship is not a fine weather craft, and that with adequate ground organisation there is no reason why it should not fly anywhere in the world under any conditions.

I have tried to indicate from the pilot's point of view the main point to be considered in the design of ships of increased size, namely, the increase of speed, both to enable good regular flights to be made under all weather conditions and to reduce the difficulties from superheating.

I have dealt entirely with the ship in the air, and leave it to someone else to discuss the ground organisation, one of the chief features of which is airship mooring.

This mooring is now an accomplished fact and only wants developing to make it of practical value, and I hope I have shown that, as soon as mooring of airships has been developed, the airship for long-distance regular schedule flights is a sound practical proposition.

APPENDIX A.

THE EFFECT ON THE CHARACTERISTICS OF FLIGHT IN THE VERTICAL PLANE OF A DIFFERENCE BETWEEN THE WEIGHT AND BUOYANCY OF AN AIRSHIP.

Referring to diagram 1:—

R_1, R_2, etc., represent direction of the resultant wind force on a ship, corresponding to inclinations of the relative wind to the axis of the hull, α_1, α_2, etc. The angle ψ and the distance x measured along the axis from the centre of buoyancy, define the line of action of R. x will be considered positive when measured from the C.B. towards the nose.

Diagram 2 indicates the effect of an inclination of the control planes.

The conventions of sign adopted are shown on diagram 4.

In a modern rigid airship x is comparatively large and positive when ϵ is zero and α is very small, and x decreases as α increases. x further decreases with increase of ϵ of the same sign as α.

ψ increases with α, at first being rapidly, and afterwards more slowly, as ψ approaches 90°.

ψ also increases with increase of ϵ of the same sign as α when α is small.

ψ may be expressed as $f_1(\alpha, \epsilon)$ and x may be expressed as $f_2(\alpha, \epsilon)$.

These functions may be determined from model experiments.

Case I.

Consider first the conditions for equilibrium in the vertical plane of an imaginary ship in which the centres of buoyancy and gravity coincide and the line of thrust passes through this common centre along the axis of the hull.

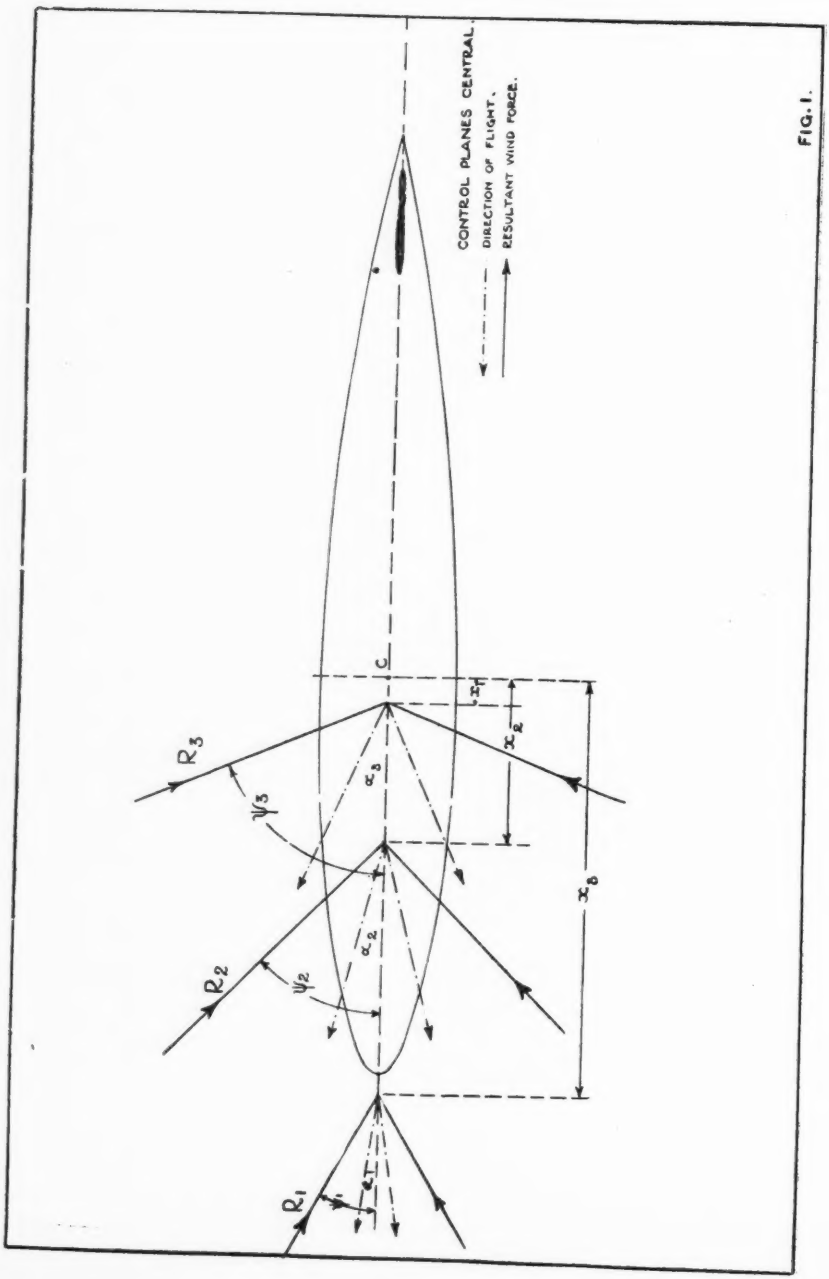

CONTROL PLANES CENTRAL.
DIRECTION OF FLIGHT.
RESULTANT WIND FORCE.
C
x_1
x_2
x_3
R_3
ψ_3
α_3
R_2
ψ_2
α_2
R_1
ψ_1
α_1

FIG. 1.

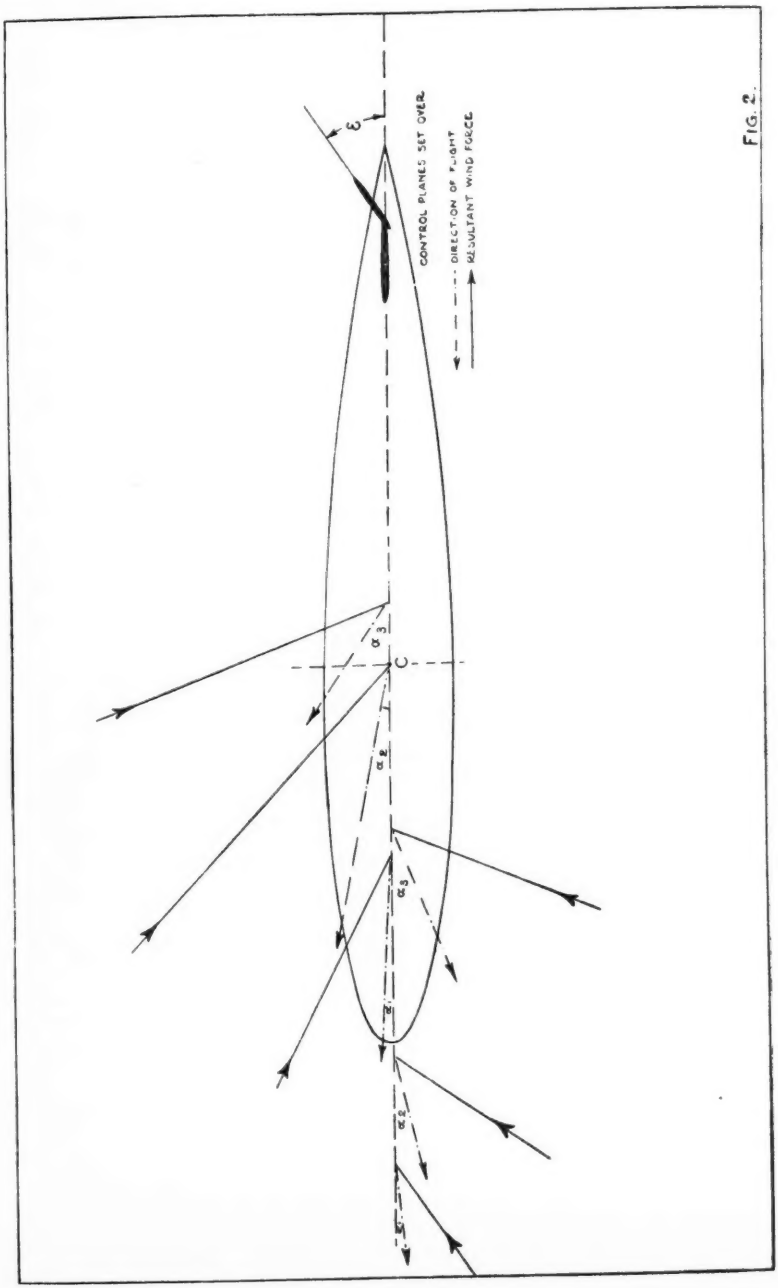

CONTROL PLANES SET OVER
DIRECTION OF FLIGHT
RESULTANT WIND FORCE
C

FIG. 2.

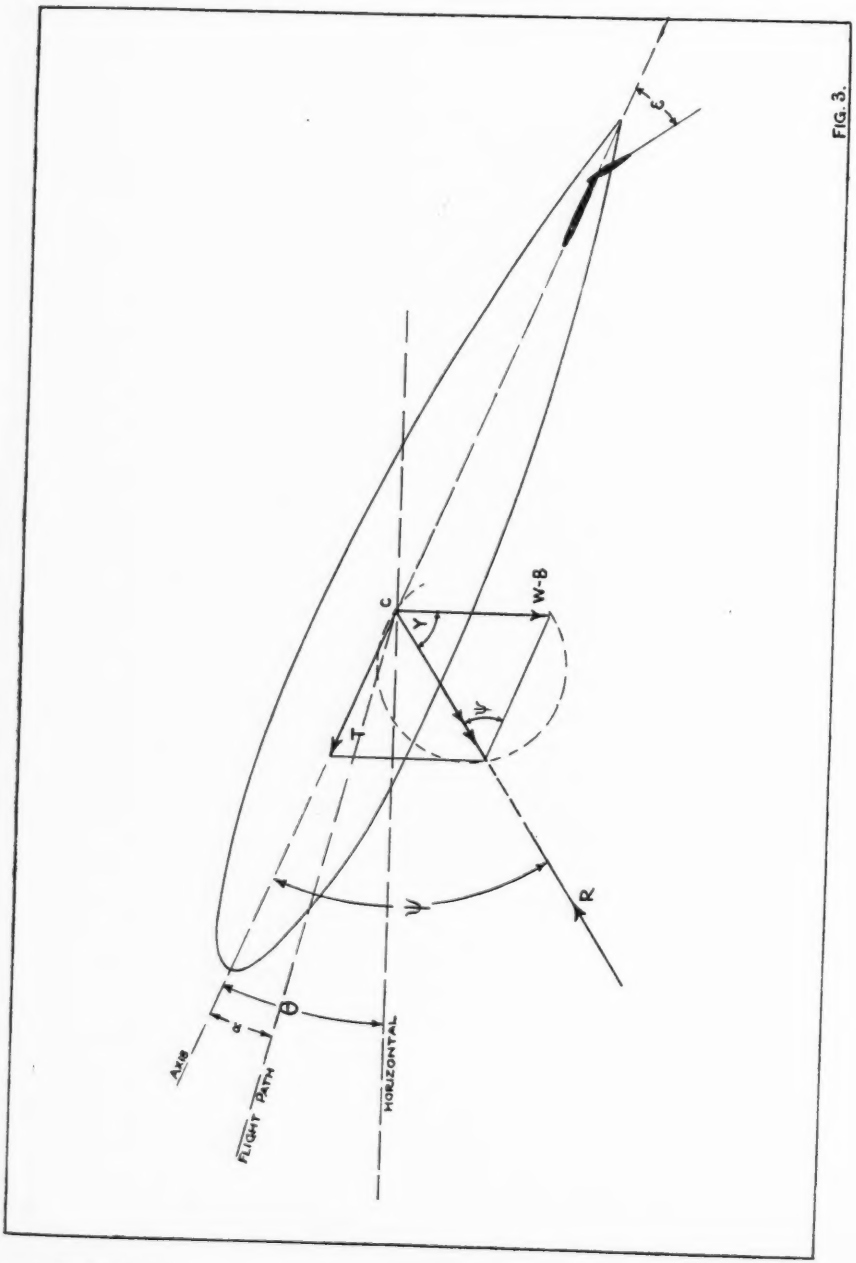


FIG. 3.

In diagram 3:—

W is the gross weight of the ship, including gas.
B is the weight of air displaced.
θ is the inclination of the axis of the hull to the horizontal.
T is the propeller thrust.
R, α, ψ, ϵ have the meanings assigned to them previously for diagrams 1 and 2.
γ is the angle between R and the vertical.

For equilibrium in rectilinear flight, the resultant of T and $W - B$ must be directly opposed to R.

Therefore

$$T/(W - B) = \sin\gamma/\sin\psi$$
$$= \cos\theta\cot\psi + \sin\theta$$
since $\gamma = 90^\circ + \theta - \psi$
so that $\sin\gamma = \cos(\psi - \theta)$

or

$$T/(W - B) = \cos\theta\cot f_1(\alpha, \epsilon) + \sin\theta \quad . \quad . \quad . \quad (1)$$
$$\text{and } x = f_2(\alpha, \epsilon) = 0 \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Hence for any given position of the control plane, ϵ, the values of α and ψ are determined by the relation (2) and the variation of the ratio $T/(W - B)$ can only be met by varying θ.

If the range over which ψ be varied by varying ϵ (equation (2) being satisfied) be relatively small (as in the present ships), it may be seen that the direction of flight, $\theta + \alpha$, is much dependent on the ratio of $T/(W - B)$.

In diagram 3 a "heavy" ship is shown, *i.e.*, $W > B$. Suppose ϵ and $W - B$ constant, and consider variation of T.

Since ψ is constant, the vector representing the resultant of T and $W - B$ must terminate on the dotted circle. At low values of T the ship would descend. As the thrust is increased θ will increase until above a certain speed the ship will climb. (Similarly, if the ship were "light" it would then descend.)

As T approaches in magnitude to the diameter of the circle the ship will become less stable. There will be two possible values of θ when T is $>(W - B)$ but less than the diameter.

Finally, when T exceeds the diameter of the circle defined by $W - B$ and ψ, equilibrium will only be possible with a curved flight path thus

if "heavy," or

if "light."

The behaviour may be compared to that of an aeroplane having inherent longitudinal stability, the elevator being supposed fixed and the thrust varied.

If $W - B = 0$, the only *stable* flight path would be circular, as is true of flight in the horizontal plane, the component of R at right angles to the axis being balanced by the centrifugal force.

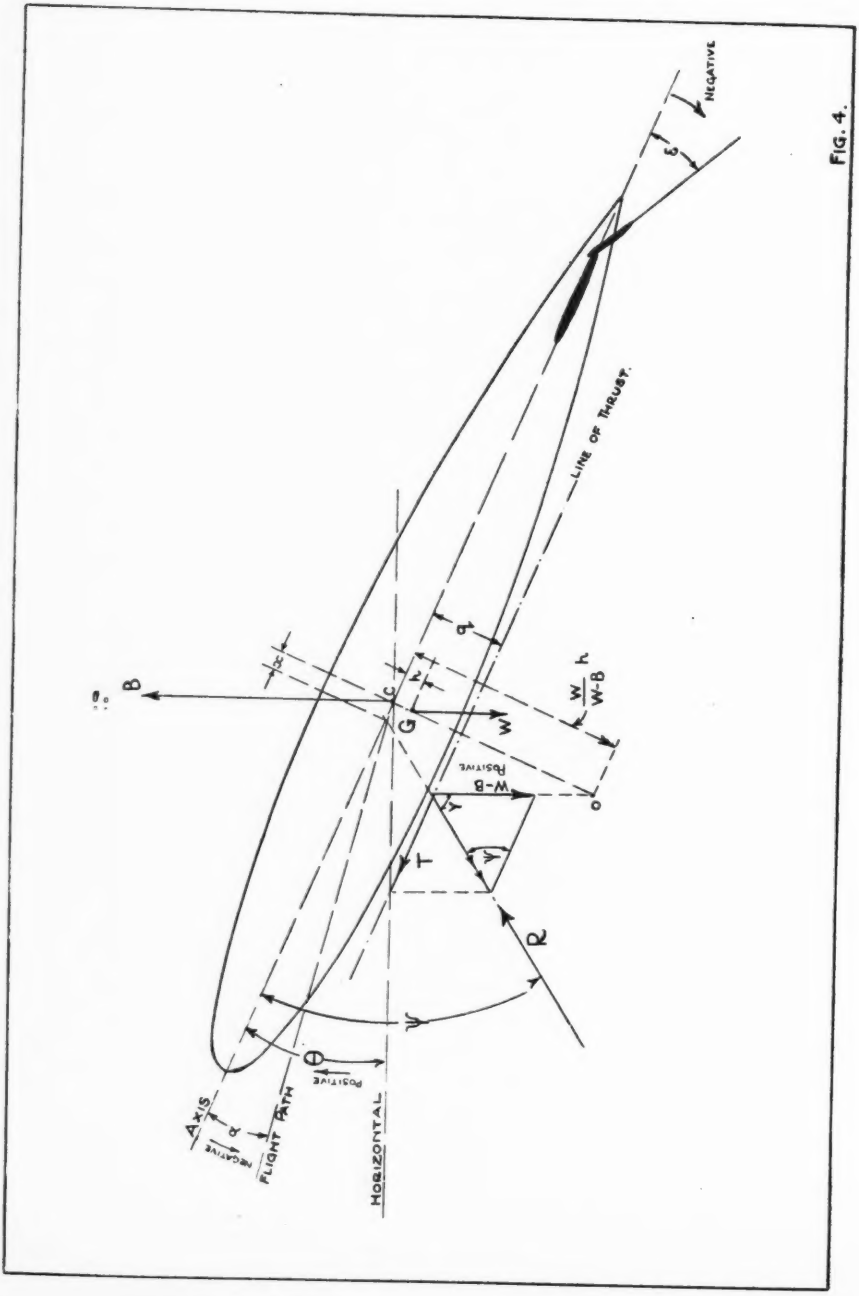

NEGATIVE
δ
LINE OF THRUST
q
B
α
C
h
G
W
W/W-B h
W-B
Positive
T
R
ψ
Θ
Positive
Axis
Negative
α
FLIGHT PATH
HORIZONTAL

FIG. 4.

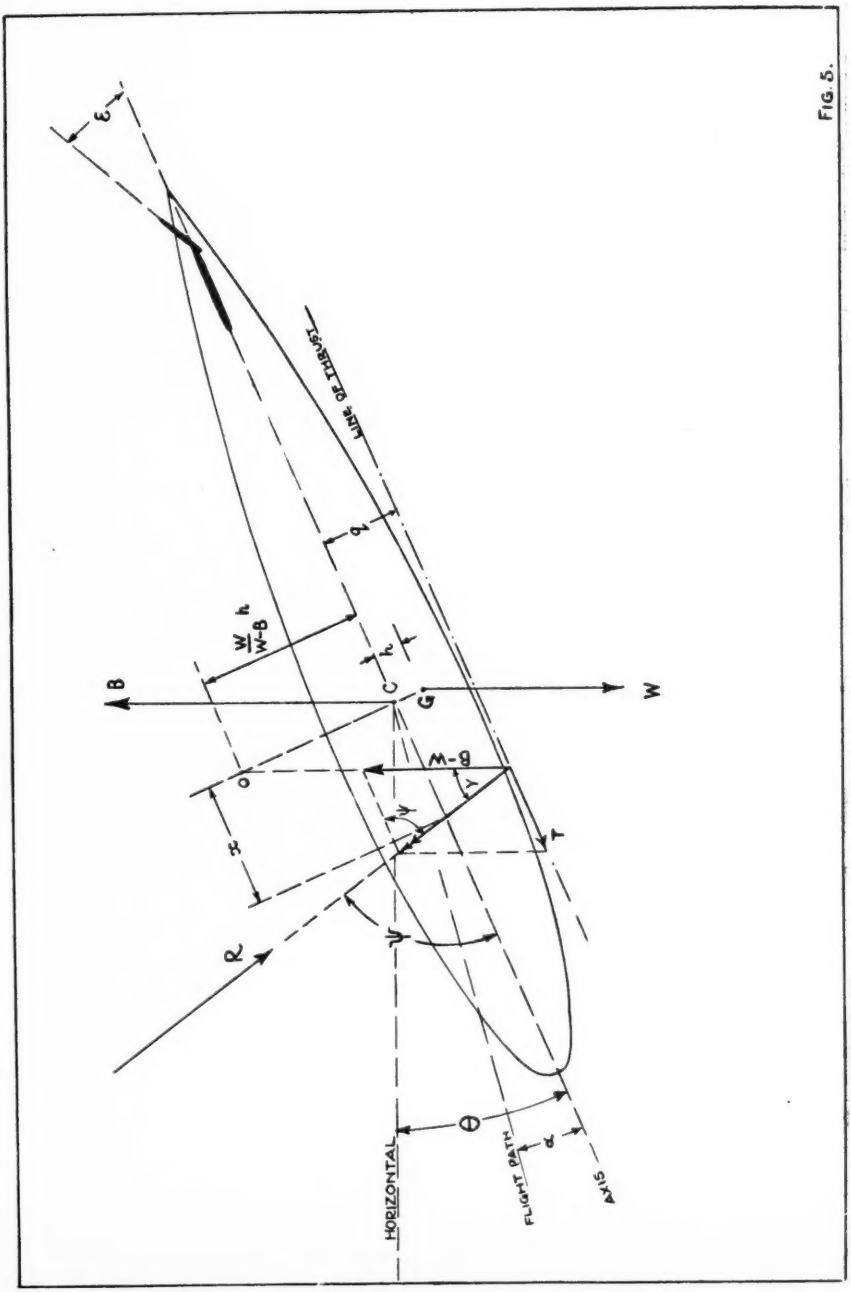

ε
LINE OF THRUST
q
W/W-B h
h
C
G
B
W
M-g
γ
ψ
T
o
x
R
Ψ
Θ
HORIZONTAL
FLIGHT PATH
α
AXIS

FIG. 5.

If $W - B$ vary, any given conditions will be obtained at the same value of $T/(W - B)$, so that, for instance, the maximum speed of horizontal flight (when "heavy" with elevator hard down, or when "light" with elevator hard up), or the speed at which flight becomes unstable, will be proportional to $\sqrt{\pm(W - B)}$.

It may be noted that at the maximum speed of straight flight, when T is a diameter of the dotted circle, the angle γ is 90°, R is horizontal, and the flight path is inclined to the horizontal.

It should be mentioned that the case where $f_2(\alpha, \epsilon)$ is always zero or negative represents larger planes than can be fitted in practice, and has not been considered. Such a ship would be stable at all speeds.

Case II.

Diagrams 4 and 5 more nearly represent the case of an actual ship, in which:

h is the distance of the centre of gravity below the centre of buoyancy C.

q is the distance of the line of thrust below the axis of the hull.

Horizontal static trim is assumed.

The conditions of equilibrium in straight flight may be seen to be, as before,

$$T/(W - B) = \cos\theta \cot\psi + \sin\theta$$
$$= \cos\theta \cot f_1(\alpha, \epsilon) + \sin\theta \quad . \quad . \quad . \quad . \quad . \quad (1)$$

also,

$$f_2(\alpha, \epsilon) = x = Wh \tan\theta/(W - B) - q(\tan\theta + \cot\psi)$$
$$= W/(W - B) - q(\tan\theta + \cot f_1(\alpha, \epsilon)) \quad . \quad . \quad . \quad (2)$$

In practice, when α and ϵ are small, as in normal flight, x has a considerable positive value.

If θ is small and of the same sign as $W - B$, as in normal flight, a large value of h gives a large (numerical) value of x/θ. This enables the conditions of equilibrium to be satisfied for a large range of speed and buoyancy, with small change of θ. This increases the maximum speed of horizontal flight, but decreases manœuvrability at low speed.

The term $q(\tan\theta + \cot f_1(\alpha, \epsilon))$ changes sign with α under most conditions. Increase of q, therefore, increases x/θ when "light" and reduces it when "heavy" under normal conditions of flight, as above.

It, therefore, appears that h and q should both be kept small, particularly the latter. h and q have both relatively decreased in modern ships as compared with older types.

When $W - B$ is large x/θ becomes small and the conditions of equilibrium approach to those of Case I. Equation (1) then shows that ability to maintain θ, or $\theta + \alpha$ constant, over a wide range of speed and, therefore, of T, requires large variation of $f_1(\alpha, \epsilon)$, and/or of $f_2(\alpha, \epsilon)$ with ϵ, and, therefore, large control planes.

A value of $(W - B)/W$ of 4 or 5 per cent. is not exceptional.

This is of the same order as the thrust at full speed and in modern ships produces a maximum limit to the speed of horizontal flight well below full speed, the behaviour of the ship approximating to that deduced for Case I.

This limitation may be reduced, or removed, as has been shown, by increasing the size of the control planes. This involves increased weight and constructional difficulties.

The shape of the hull also largely affects the functions $f_1(\alpha, \epsilon)$ and $f_2(\alpha, \epsilon)$, but unfortunately shapes so far discovered which are considerably better in this respect have considerably higher resistance when $\alpha = 0$. A compromise in hull form may be found to be advantageous. It must be remembered that under

average conditions of flight α is not zero, and, consequently, the form which has the lowest resistance when $\alpha = 0$ may not be the best.

Considering similar strips of varying linear dimension, L, at speed V.

R and T vary as L^2V^2.
$W - B$ and W vary as L^3.

Therefore similar strips of varying size will behave in the same manner at speeds proportional to $\sqrt{L}$.

Flight-Lieutenant F. L. C. BUTCHER, R.A.F., delivered the following lecture:

AIRSHIP MOORING AND HANDLING.

Introductory Remarks.

At the present time, although an airship can navigate in very strong winds, when in the air, great difficulty is experienced in handling her on the ground, and many opportunities of flying are missed for this reason.

Although it is possible to leave the sheds in doubtful weather, there is always the chance that if the wind freshens considerably, she may be forced to remain out several days, or that serious damage may be done if an attempt is made to land and take her into the shed.

It is, therefore, essential to the success of airships in the future that the mooring problem must be solved to enable them to be quite as independent of their sheds as a sea-going liner is of her dry dock. Not only would a satisfactory system of mooring enable airships to leave the ground and land in far stronger winds than at present, but it would considerably reduce the number of men required for a landing party.

This problem is so complex that it is impossible for me to go into details in the time at my disposal, but I will endeavour to explain the various methods which have been tried in this country with their advantages and disadvantages.

Handling by Means of Landing Party and Windscreens.

When a large airship lands the fore guys are caught by the landing party detailed for them and run out at right angles to the centre line of the ship, thus ensuring that her bows are kept pointing "up wind." The ship is hauled down until the cars are in the hands of the car parties, who keep them from dragging along the ground or rising too far off it.

After ballasting up to ensure sufficient lightness for handling, the ship is walked towards the doors of the shed by the parties on the fore handling guys and bow rope.

I will take as an example the most difficult case usually experienced in housing a large rigid (*i.e.*, a wind blowing across the direction of the sheds), and explain the method employed to get the ship in. The bows are manœuvred into a position as far to windward of the doors as the windscreens allow (see Fig. 1), and the stern is walked towards the shed by the men on the after guys. The bows are eased away from the wind, but kept well in hand and not allowed to drift to leeward of the centre line of the shed. When the ship is lying in the position shown in Fig. 2, she is walked bodily astern, the bows being allowed to drift towards the centre line of the shed as the stern moves further into the shed.

If, in the course of taking the ship in, she drifts dangerously near the side of the shed, it has been found that she can be rushed out again more easily when this method is employed than if she is taken in bows first.

When the wind is blowing "up and down" the sheds, the ship may be taken in at either end of the shed, and a considerable difference of opinion exists as to

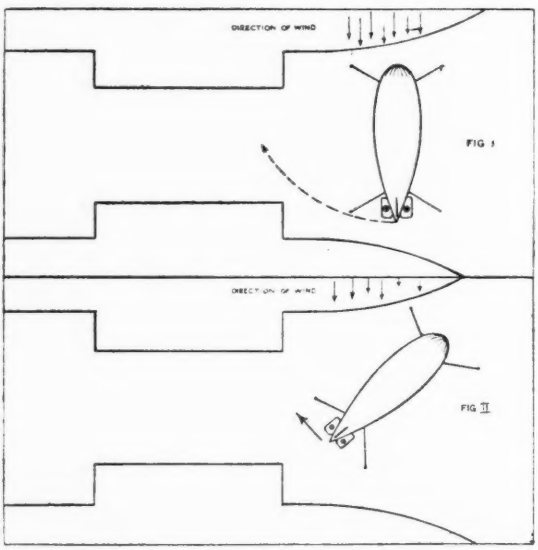
which is the better method. If the ship is taken in through the leeward doors, handling is rendered difficult owing to the bumps and eddies caused by the shed, but in the event of the ship "taking charge," she is more likely to drift clear than if the windward doors were used. By opening the windward doors slightly, and allowing a current of air to blow through the shed, the state of the air on the leeward side is improved to a great extent.

In strong winds it is found that the ship rises and falls very rapidly owing to gusts and the downward component of the forces on the guys. This movement is at present checked by the parties on the cars, but in larger ships the cars will be so small compared to the bulk of the ship that handling frames of light structure extending from the keel girders to the same level as the bottom of the cars will have to be used. These frames have been in use in Germany for some years, and have been tried and found satisfactory in this country.

The above description gives an idea of the difficulties of housing a large airship, and shows the necessity of advancement in this direction, either by mechanical handling or by mooring the ship out when the wind is strong.

The Advantages and Disadvantages of Windscreens.

The windscreens used in this country are of two distinct types, the solid windscreen, which allows no air to pass through it, and the screen made out of expanded metal which reduces the velocity of the air passing through it by about 80 per cent. The protection of the solid screen is felt in winds of low velocity, especially light cross winds, and a ship which is being taken into the shed may be relieved of considerable strain by keeping her well under the lee of the screen until very close to the mouth of the shed.



In strong winds, the air, after being forced up out of its path by the screen, naturally descends as soon as it can, causing a suction and a bad down current some 15 or 20 yards to leeward.

This makes airship handling difficult under certain conditions. Expanded metal screens are a distinct improvement on the type described above as they do

not cause such gusts and differences of pressure, and a ship can be housed in a steady wind of about 20 per cent. of the outside ground wind.

The use of windscreens has been discontinued, as, in the case of large airship sheds, they would have to be placed so far apart owing to the large manœuvring space required by a modern airship that they would be practically useless.

In Germany windscreens are not used at all, and mechanical handling by means of trollies and rails is invariably employed.

The following is a short description of their method.

Mechanical Handling.

In each double shed four sets of rails are laid down and extend to a distance of about 1,000ft., as shown in Fig. 4. The rails are of I-section and the set consists of three, one horizontal and two vertical, Fig. 3. The trollies are fitted with four wheels, running inside two vertical rails which take the lifting and upsetting forces, and six wheels running on the horizontal rail to take the side thrust. All wheels are fitted with roller bearings, and brushes are placed both in front and behind the trolleys to keep the rails clear, thus ensuring smooth running.

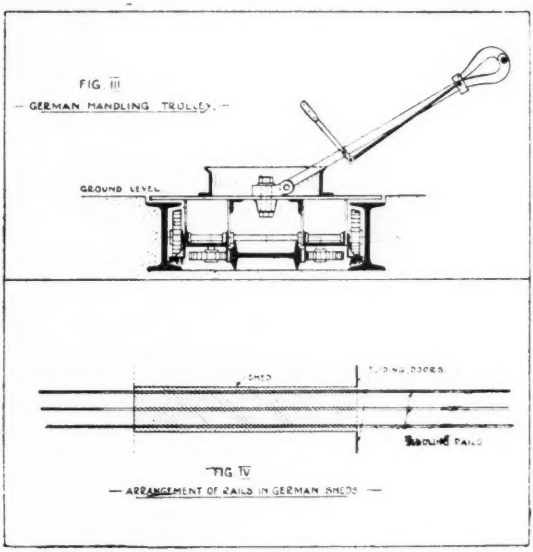


FIG. IV
— ARRANGEMENT OF RAILS IN GERMAN SHEDS —

To take a ship in by this system, the following method is employed:—

The ship is landed as near as possible to the end of the rails and walked up to them, rope tackles are led from two trolleys (one on each rail) to the mooring point and hauled taut. The ship is then walked towards the shed by parties of men on the bow hauling rope and fore guys until the stern can be hauled up to the rails and secured in the same way as the bows.

Each trolley is fitted with ropes which are manned by not more than eight men who keep them abreast of the ship. The rest of the handling party are employed on the bow hauling rope, fore guys, and underneath the car and handling frames to prevent the cars from bumping along the ground.

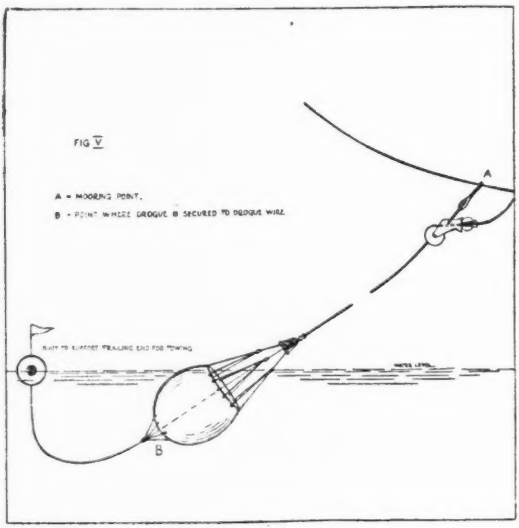
The ship is taken out of the shed in the same way until she is clear, then the aft guys are manned, the tackles eased off, and the stern allowed to swing in

the direction of the wind. The bows are hauled out to the end of the rails, by which time the fore guys can be manned and the bow tackles eased off.

This method of handling is very simple and undoubtedly superior to our method of handling parties and windscreens; it enables the ships to be taken out in cross winds up to 25 m.p.h., without risk of damage, with two-thirds of the landing party usually employed.

In 1917 and 1918 experiments with tractors were made with the object of reducing the landing party required to handle a rigid airship. Each fore guy was secured to a tractor, and the ship was towed towards the shed. This scheme, however, was given up owing to the severe shocks transmitted to the structure by the tractors rising and falling over bumps on the aerodrome, the noise of their engines, and their inability to manœuvre quickly.

On one occasion it was necessary to take R.9 into the shed at Howden in a cross wind of about 30 miles per hour, and a tractor was used to tow the ship forward. In the course of taking her in she was damaged considerably against the side of the shed, but had not the tractor been used she would have, in all probability, broken away.



Mooring Over the Sea.

When airships are patrolling or carrying out prolonged flights over the sea there is always the possibility that the wind may increase to such an extent that the ship runs out of petrol before making her base; in this case the only thing to be done is to drop a sea anchor or drogue and signal to surface craft for assistance and a tow to the nearest place where petrol is obtainable.

The following is a short description of the tackle usually fitted in rigids for riding to a drogue. The general arrangement can be followed by referring to Fig. 5.

The drogue itself is made out of stout canvas roughly in the shape of a bucket, strengthened round the rim by roping, and eyeletted to take the twelve bridles which, in groups of three, are hooked in the jaws of the drogue slip. The drogue wire is continuous from the bows of the ship through the slip and drogue, which are fitted some 30 to 40 feet from the end, thus leaving sufficient wire trailing behind to be picked up and secured by the towing ship before the drogue is spilled.

The slip (see Fig. 6), which was especially designed for this purpose, is operated by the impact of a weight sliding down the drogue wire, and can be described as follows:—The bridles for the drogue are held by four hooks pivoted on the body of the slip, and which in the normal position are guarded, as shown in the figure, to prevent the bridles from becoming unhooked when the drogue is dropped.

These hooks are held in position by extensions or arms with hooked tongues fitting over the rim of a cup sliding on the central guide. The cup is held up by a strong spring and has a projecting top which is struck when the weight is released and slides down the wire. When the weight hits this projection the cup is forced down against the spring, thus releasing the arms, which immediately fly outwards, due to the strain on the hooks, and the bridles are slipped. It has been found that an eight-ounce weight will spill the drogue when dropped from about 75ft., though the slip is several feet under water.

The extension of the drogue wire passes through the bottom of the drogue, which is secured to it at this point, so that when the bridles are slipped the drogue turns inside out, enabling it to be drawn out of the water.

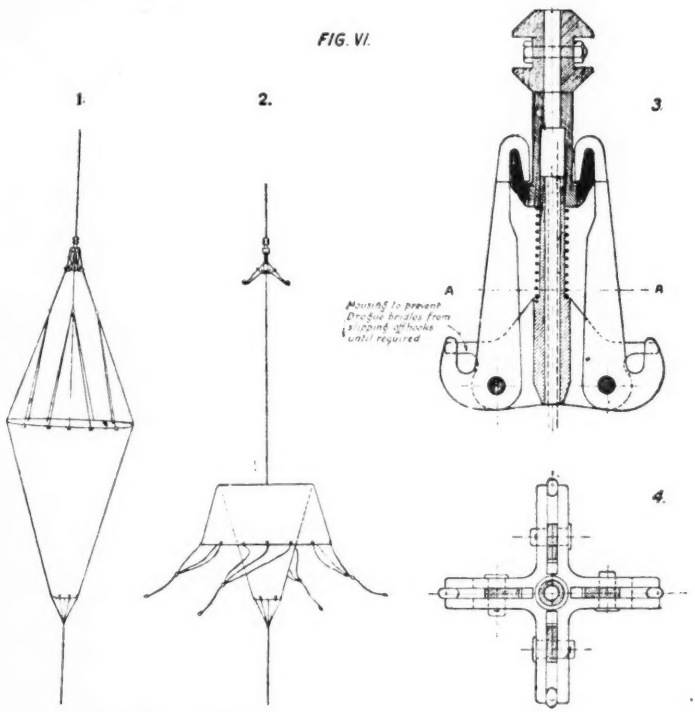


FIG. VI.—*Arrangement of improved S.O.B. Slip. 1, Drogue in position for use; 2, Drogue "slipped"; 3, Vertical section; 4, Horizontal section through A-A.*

This fitting was found necessary owing to the fact that the large drogues used hold from four to five tons of water, and would either have to be cut adrift or lifted bodily out of the water, which is inadvisable owing to the alteration of trim and waste of ballast necessitated.

The pull in the drogue wire is transmitted to the ship by means of a ball-stopper wedged on to the wire, which takes up against a block secured to the mooring point with a wire strop seen in Fig. 7.

As soon as the pilot decides to ride to a drogue, the required length of wire is reeled off the drum and the ball-stopper wedged securely at a distance from the drogue corresponding to the height at which it is desired to ride, allowing a margin for the sag in the wire. The wire is paid out in a loop from the bows, keeping the drogue still in the ship, until the stopper comes up against the block attached to the mooring point.

The drogue is dropped when the ship is about 100 to 150 feet above the water and carrying as little way as possible. As the ship drifts with the wind the drogue, by being towed through the water, fills, thus keeping the bows of the ship into the wind.

The drogue, of course, does not hold the ship stationary over the water, but retards its drift to such an extent that even in strong winds the drogue wire can be picked up by surface craft and made fast for towing.

Experiments were carried out by R.9 and R.23 over the Wash with drogues in 1918, and it was found that it was only advisable to ride to a drogue in cases of emergency, until some satisfactory arrangement was made to enable the ballast bags to be filled fast enough to counteract the lightness caused by superheating. The airships in both cases were successfully taken in tow by a motor boat, and the drogue wire secured to a buoy, thus showing that in the case of a broken-down airship at sea it is not a difficult matter to salve her.

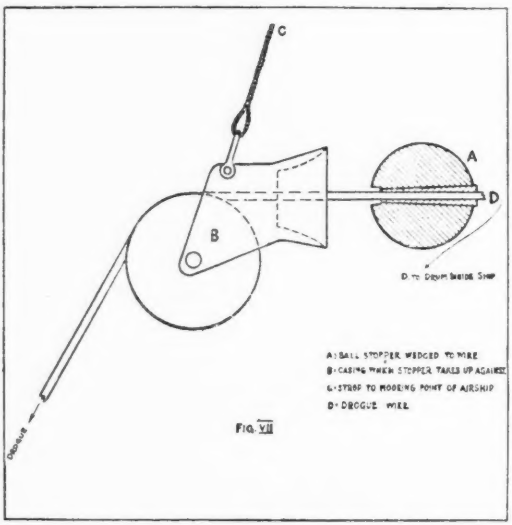


FIG. VII

This brings up the question of long distance airship towing by surface craft.

In July, 1919, N.S.7 was towed from Newcastle to Southend by H.M.S. "Furious," steaming at 17 knots, and although the tow-rope parted once owing to a faulty splice, a line was lowered and the rope hauled up and made fast again. In winds of over 30 miles per hour the airship kited when H.M.S. "Furious" was not under weigh, but it was possible to counteract this by running one engine slowly.

This series of experiments show that it is possible for an airship to work in

conjunction with surface craft at a considerable distance from her base, and if the parent ship was provided with fuel and gas, the airship could operate for several weeks.

Mooring Over Land.

This subject can be divided into two parts, Mooring by Wires and Mooring to a Mast.

Mooring by Wires.

The first system of mooring an airship in this country was known as the Usborne system, and in this case the ship was secured to one point on the ground by two wires, one vertical from the mooring point and one made fast to the car. The ship was steadied by wire guys led aft from the mooring point at an angle of about 120°, and secured to posts.

Several early Non-Rigids were moored by this system in the beginning of the war, but were not strong enough to stand high winds, and therefore experiments on these lines were discontinued.

Three-Wire Mooring System.

The incident which led to the reconsideration of mooring an airship by wires occurred in 1917, when R9 returned from patrol short of fuel with a strong wind blowing. It was decided to hold her out on the landing ground until the wind

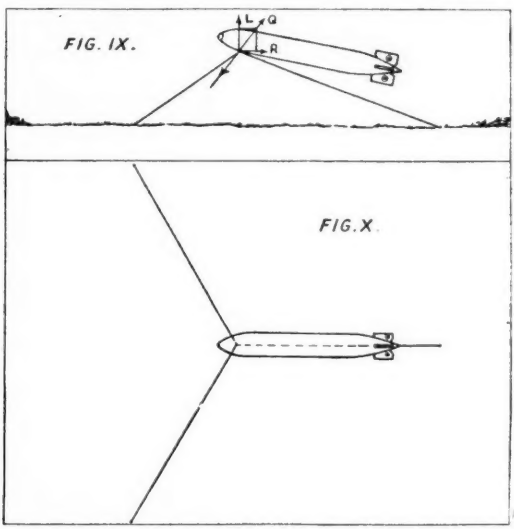


FIG. IX.—*Diagram of forces in three-wire system.*
FIG. X.—*Diagram of open hawse position, Mark I.*

moderated, but such difficulty was experienced in keeping her steady that the captain secured the mooring point to three bollards which formed a triangle on the ground. Owing to the satisfactory results obtained, further experiments were carried out, from which the three-wire mooring was developed.

An airship was moored to three wires secured to posts or bollards sunk in the ground at the apices of an equilateral triangle, and spliced to a swivel at the mooring point of the ship.

The forces acting on a rigid airship moored to this system may now be considered :—

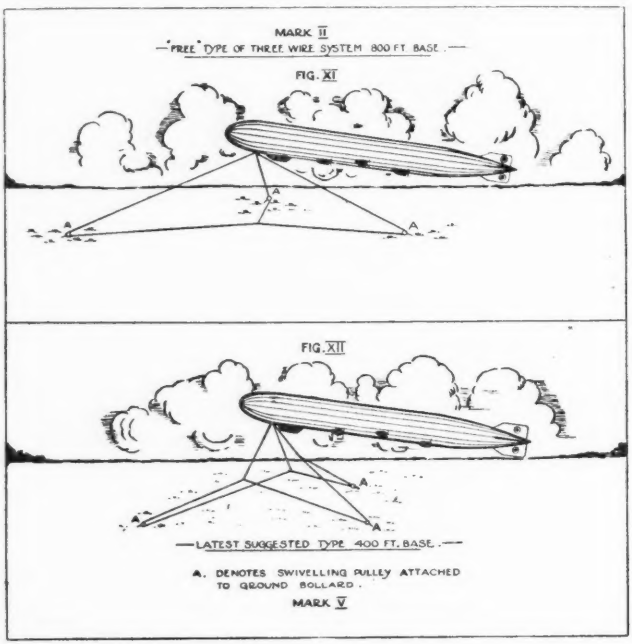
It was required to maintain the ship at an altitude of 200ft., pitched slightly down by the stern, as shown in Fig. 9.

The forces acting on the ship at the mooring point are as follows :—

L = The vertical lifting force composed of the static lift due to the buoyancy of the ship and the dynamic lift due to the angle at which the ship is pitched.

R = The backward force caused by the wind pressure on the hull and cars.

By completing the parallelogram of forces, the resultant force Q was found, and from this the angle of the wire was calculated to give the necessary equal and opposite force when the ship was lying in the " open hawse " position, shown in Fig. 10.



It was found that the ship, when moored to this system, was driven backwards and downwards by gusts, causing the leeward wires to slacken and tighten up with a sharp jerk which strained the structure round the mooring point.

Further experiments were carried out in a wind tunnel, with the result that it was decided to moor an airship to a modified system (see Fig. 11). The same bollards were used as in the last trials, but the wires were spliced into a central ring and led through blocks on the bollards to a swivel at the mooring point of the ship 200ft. above the ground. The ring, therefore, was free to move within the triangle formed by the posts, and in this way the wires were kept taut the whole time.

R26, an obsolete ship due for deletion, was strengthened in the bows by additional diagonal wiring extending over frames two and three, and when this

was completed, was walked out of the shed and secured to the swivel on the mooring system. The trim of the ship was altered until the forward part was sufficiently light to lift the weight of the wires, while the tail was kept in equilibrium and was allowed to rise until the wires were taut.

The ship remained out for ten days, and the following experience was gained:

During the first six days, the winds were light, and did not exceed 10—15 miles per hour; the nights were very cold, followed by hot sun, and, owing to the slow and inadequate means of transferring ballast to the ship, she became very light, due to superheating, and on two occasions the stern rose until the ship was riding at an angle of 25 degrees.

A kite balloon winch was used for hoisting ballast up to the ship, and ropes were hung from the four after-handling guys on which sandbags were secured as compensating ballast. Difficulty was experienced with this compensating ballast, as each time the stern passed over one of the mooring wires the ballast had to be unhooked, the rope passed over the wire, and the ballast hooked on again the other side; this required a party of about six men standing by, and in gusty weather caused a lot of work and supervision.

On the ninth day the wind got up from the East and gradually increased to 35 miles per hour. Throughout this period the ship rode steadily, yawing slightly until the rudders were lashed with about three degrees of port helm on. This had the effect of reducing the tendency to yaw by keeping the wind more on one side than the other; consequently the ring on the ground shifted about 100ft. ahead and 50ft. to port of the central position, but moved back and remained fairly steady between this point and the centre. The friction of the wires moving across the ground damped the yawing motion of the ship considerably.

Heavy rain fell in the evening, and owing to the porous condition of the outer cover, the ship collected about two tons of water, but did not seem to get any heavier in spite of the continuous rain.

At midnight the wind backed to N.E. and rose to 35 miles per hour with gusts to 45 miles per hour, changing the direction of the ship to midway between two wires and shifting the ring to a position 60ft. ahead and 20ft. to port of the centre. The yawing motion continued, but the ship showed no tendency to move forward or aft when struck by gusts, excepting on one occasion when the wind suddenly shifted a point for a few seconds and drove the ship very near the ground.

Early next morning snow fell and forced the ship down to the ground, as R26 was an obsolete ship and had not enough disposal lift to counteract it. She lay steady on the ground, rolling slightly from side to side in a wind of 35 miles per hour, and a good deal of structural damage was done.

In the afternoon the snow melted, and when the cars were taken off, the ship rose and remained steady throughout the night. She was taken into the shed next day owing to the damage done while on the ground, and on examination it was found that the hull in the vicinity of the mooring point was not strained.

The conclusions drawn from this experiment were:—

(1) That the ship rides best at an angle of 4 to 5 degrees down by the stern with about the same number of degrees of helm on in order to keep the bows slightly off the wind.

(2) That a quick system of filling the ship with ballast is absolutely essential to prevent the stern from rising to a dangerous angle when superheating.

(3) That a ship could ride out any ordinary blow when moored out to the three-wire system, provided that the mooring point is structurally strong.

(4) That a ship with a reasonable lift must be used so that the necessary reserve of ballast can be carried to meet adverse changes in weather.

(5) That a ship returning to base is usually short of ballast, and therefore gassing and ballasting arrangements must be provided.

The advantage of this method is that it can be prepared in a very short while, at a small cost, and is effective in an emergency. Moorings of this type could be placed at points on an airship route in case a ship is unable to get to the next mooring mast owing to engines failing in a strong wind.

The disadvantages are :—

(1) The petrol and water hose have to be disconnected and the turns taken out of them when the ship swings, as a hollow swivel was found to be too heavy for use.

(2) The difficulty of changing crews and taking in supplies.

(3) The large space of level ground required for this system, owing to the size of triangle necessary to keep the ship steady at the " open hawse " position.

R.34 at Mineola.

R.34 was moored to this system after landing from her trans-Atlantic flight at Mineola, behaving well and riding steadily.

On one occasion, however, after a heavy rainstorm she came down to the ground, but rose again when gassed. On the following morning when the sun came out, the rain dried off and the ship superheated so quickly that ballast could not be taken on board fast enough with the arrangements available. The casting at the mooring point broke, but luckily held the ship until she could be hauled down and more water taken aboard.

R.34 remained there for four days and rode out some very gusty weather, thus demonstrating the usefulness of the three-wire mooring system in the case of an emergency.

Since that date wind-tunnel experiments resulting in two modifications of this system have been made. In the first, the three wires, instead of being spliced to a ring, are brought to the three corners of a parallelogram; the fourth corner is held by another wire secured to a bollard. It is claimed that by this method the movement of the wires will be damped to a considerable extent without causing jerks on the structure of the ship (Fig. 13).

The second method, shown in Fig. 12, has been developed because, in modern streamline ships, wires from the mooring point to a triangle of 800ft. base would foul the fore-car when the ship swung. The base in this case is 400ft., and theoretically better results will be obtained than with an 800ft. base, but neither of these modifications have been tried on a full scale.

Other Methods.

Occasionally during the war non-rigid airships were unable to return to base owing to engine breakdowns in strong winds. In the case of small airships, such as the S.S. type, they were landed as free balloons and deflated without much damage.

In December, 1917, however, a North Sea type of 360,000 cubic feet capacity was caught while at sea in a wind of 35-40 m.p.h. with one engine broken down. The coast was reached eventually, but as no headway could be made with one engine against the wind the captain decided to land, and endeavour to moor the ship out behind a hedge until the wind moderated sufficiently to enable him to fly back to base.

The ship was flown down to within a few feet of the ground, head to wind, the second officer and second coxswain jumped out, caught the fore guys and secured them to the hedge. These kept the ship steady in the wind for several hours, but eventually the port guy broke and deflation was resorted to.

In the summer of 1918 a great number of S.S. Zero type airships were used to escort merchant convoys as a protection against submarines, and, owing to the small shed accommodation available, were moored out at sub-stations along the coast. A tall wood bordering on a good landing field was selected as a site for the station, and a clearing made in the centre of it sufficiently large to hold the ship; this clearing was connected to the landing field by a lane through which the ship could be walked.

To moor a ship in the clearing the guys were taken out at right angles to the centre line and secured to trees. Two additional guys were fitted to patches on the top of the envelope to prevent excessive rolling and made fast in the same manner. The car was ballasted down until it rested on the ground, and the tail held down by a rope to weights on the ground.

This method was in use at all small stations situated near the coast, and in many cases winds of 40-50 m.p.h. were weathered without damage to the ships.

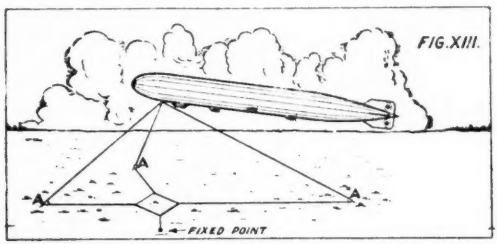


FIG. XIII.—*Modified "free" three-wire system, 800ft. base, Mark IV.*
(A) Denotes swivelling pulley attached to ground bollard.

Regular patrols were carried out from these mooring stations, and when repairs were needed the ship was flown back to base and another substituted.

Mooring to a Mast.

Attempts were made to moor out non-rigid airships to a mast designed at Farnborough and erected at Kingsnorth. The top of the mast revolved and consisted of a hollow cone, the base of which was padded to fit round the nose of the airship. This cone was pivoted at its apex, and a balancing weight was fitted on a short arm on the opposite side of the pivot. The nose of the ship was strengthened and a mooring wire spliced into it.

When it was necessary to moor out an airship the nose was brought as near as possible to the cone by the landing party, and the mooring wire led through the padded ring over a block at the apex of the cone and down to a small winch, which, when operated, hauled the nose of the ship into the cone. This method proved satisfactory in light or steady winds, but in gusty weather, when the movement of the ship was rapid, a bending stress was set up in the fabric just behind the ring; this wrinkled one side of the nose and put a corresponding tension on the other, which tore the fabric after a short while.

The reason for this was the fact that a few feet of the nose were held inside the cone and that the point of attachment of the ship was not directly above the pivot of the top of the mast.

The cone was done away with, and a ship was moored directly to the top of

the mast, but it was found that the fabric was not strong enough to stand the force of the wind on the ship. Consequently an axial spar, stayed to the after ends of the nose stiffeners and projecting through the nose, was fitted to a ship, and the spar secured to the top of the mast. This system was tried out with satisfactory results until the spar broke, and the experiments were discontinued for the time being.

Trials were also carried out at Barrow in 1918 with a small non-rigid moored to the top of a mast and secured to it at the point where the fore guys are fitted, but the ship rolled badly and the following system was evolved from it.

Barrow Mast Mooring System for Non-Rigids.

In this case the ship is attached at two points on opposite sides of the nose to the two sides of a crutch mounted on a vertical mast; this crutch is built solid with the mast, which is free to turn a ball and socket bearing at its base, while it is supported just below the crutch by six guys fastened to one part of a roller bearing, the other part being solid with the mast.

The envelope is fitted with ring patches at the points of attachment consisting of a circular steel plate with a ring bolt through the centre sufficiently free in the plate to allow the ship to turn in the vertical plane. This steel plate is held in position by eight wires, and backed up by wires leading to the same number of patches stuck on the envelope. The space between the back of the ring and the envelope is fitted with a rubbing pad to prevent the envelope from being injured by chafing.

The two sides of the crutch on the mast are fitted with circular pads which correspond to the curvature of the bows of the ship, and are parallel with the patches described above. Two small hand-operated winches are also fitted opposite to the holes in the circular pads. Before bringing a ship to the mast it is turned so that a line drawn through the pads would be at right angles to the direction of the wind, then the ship is walked as close as possible to the mast by the handling party.

A wire led from another small winch at the foot of the mast through a block in the bottom of the crutch is secured to the mooring point of the ship, and the ship hauled down until two men, one stationed on each bow, are able to secure their winch wires to the ring bolts on the envelope.

By hauling in on these winches, the ring patches are brought hard against the pads on the bows, and the ship is secure. To keep the ship as nearly as possible in equilibrium, chains are made fast to the car and allowed to trail on the ground; thus, when the ship becomes light, extra chain is lifted, and if the reverse happens and she commences to fall, more weight of chain is supported by the ground.

Experiments were carried out at Barrow-in-Furness with an S.S. Maurice Farman type non-rigid of 70,000 cub. ft. which was moored out for eight days successfully. Although the winds experienced during this period were light, the experiment proved the value of this system, and further tests were carried out at Pulham, by which it was proved that a non-rigid could remain moored out in winds of over 40 miles per hour without sustaining damage.

Experiments with Rigids.

Approval was given in 1918 for the construction of a mast. The mast consisted of a steel tower with a revolving top, and was erected at Pulham. The bows of R.24, an old type of airship, were strengthened for this experiment.

The bows of the ship were fitted with a ball supported by steel tubes projecting about six feet, and on the revolving mast head was a socket in which this ball was

held, thus allowing the ship to pivot up and down about the nose, but no fore and aft movement was possible.

Gas, water and electric light mains were led up the mast and into the ship through a hatch in the bows, and access to the keel was arranged in the same way.

R.24 was taken out of the shed and secured to the mast by hand, the first part of the experiment being to ascertain what weather she could stand, and for what length of time the ship could remain moored out continuously. She remained out for 21 days before being brought back to the shed, and after a fortnight's work on small improvements which had been found to be necessary, was taken out again. This time she was able to remain out for 42 days continuously in all weathers, and the highest wind experienced was 45 miles per hour. During this time she behaved very well, riding easily and remaining steady in the direction of the wind.

Two men were on watch in the control car the whole time, and one on the ground to turn on the water to fill the ballast bags if she became light, or gas up if she became heavy.

By means of these gas and water mains it was an easy matter to counteract all changes in buoyancy, however rapid, caused by rain or rise and fall of temperature.

The ship rode best at an angle of 0° to 4° down by the stern, but the trim did not have nearly such a marked effect on the stability as in the case of the three-wire system.

These trials proved that a rigid airship can remain safely moored to a mast in winds up to 45 m.p.h. in spite of rain, sun, and the general deteriorating effect of the weather.

Landing at a Mast.

After these trials had been completed successfully, the ship was again brought back to the shed for minor alterations before carrying out the flying and landing tests. The following method was employed :—

On the ground a wire rope was led from a kite balloon winch through the mast and socket on the revolving top and laid out along the ground to a distance of 350ft. to leeward. The ship's wire was coiled on a drum inside the bows and the end led through the projecting ball and weighted with a 40lb. sandbag.

R.24 was flown to the vicinity of the mast with the ordinary flying crew, and after having been ballasted up about 300lbs. light, the end of the ship's wire was lowered until it could be shackled to the mast wire.

Directly the two wires were secure, the after-engine was run "astern" and the ship hauled down to the mast by the winch until the ball on the nose entered the socket on the mast and was locked in position.

This landing was accomplished in eleven minutes from the time the ship's rope was dropped to the time she was secured to the mast, and a total of seven men were employed on the landing gear. The wind on this occasion was under 10 m.p.h., the trials were successful, and it was decided to carry out further experiments by easing the ship away from and hauling her back to the mast in stronger winds.

A few days later this was done in a wind of 25-28 m.p.h., but as the winch was broken down the wire had to be manned by a party of men, which was a severe handicap, owing to the time lost between the orders and their execution. The ship yawed from side to side and showed a tendency to override the top of the mast, but was secured several times without damage.

Modifications have since been made to the mast and system in general, and it is hoped to carry out exhaustive trials with one of the 33 Class rigids in the near future.

Conclusions Drawn from the Above Experiment.

Mooring Out.

(1) That rigid airships can be moored out in safety in this country.
(2) No technical difficulties exist in re-fuelling, gassing and ballasting at the mast.

Landing to a Mast.

The general equipment and arrangements were rather too crude for completely successful results to be obtained, but it is generally agreed that with the improvements suggested by this experiment, no serious difficulty is anticipated.

Advantages of Mooring Mast System.

Mast Mooring has several advantages, namely :—

(1) The ship can be moored to a mast with very little buoyancy; in fact, the bows can be actually heavy, provided that the stern is light enough to remain in correct trim.
(2) A ship will be able to land at a mast and re-fuel before continuing her journey or patrol, and in strong winds will be able to remain moored until the weather moderates sufficiently to enable her to be taken into the shed, in the event of major repairs being necessary.
(3) The mast forms an excellent support for the gas, fuel and water mains, which otherwise would have to be lifted by the ship.
(4) A very small number of men are required to secure the ship.

Uses of Mooring Masts.

The commercial airship route of the future will have sheds, used as docks, at each terminus, and masts at which the airships can be landed to discharge passengers and cargo. The intermediate stopping places will consist of a mast and small plant for making gas, and carrying out any minor engine repairs which the ship may require before proceeding on her journey.

By this means it is hoped that airships will be rendered as independent of the weather as a sea-going ship, and will keep to scheduled sailings.

The CHAIRMAN proposed a hearty vote of thanks to the Lecturers, and said after the papers they had just listened to it struck a man who had no scientific knowledge of this work that it was only a question of time before the piloting and mooring out of airships would be practically perfect in all sorts of weather. The only question he asked now was did they know enough about the weather, whether the wind at certain heights and in certain quarters of the globe was always constant and in one direction, or was its change of direction known? It seemed to him that the meteorological experts did not at present know definitely whether the wind was regular in certain directions in certain parts of the globe; but he repeated that the mooring out system was definitely assured.

A point that always interested him and seemed to him a most important one was how many docks were necessary for a certain number of ships operating, in addition to mooring masts.

DISCUSSION.

Wing-Commander T. R. CAVE-BROWNE-CAVE congratulated the Society upon having two papers on such essentially practical points read before it. The functions of the Society were so broad that sometimes they had to discuss commercial questions, and sometimes they went into abstruse mathematics, physics, or engineering problems, but their primary function was to discuss aeronautics, and these two papers came under that head. The papers had only been read in abstract and the discussion was necessarily restricted, but he advised everybody to read the papers *in extenso*, as they contained much very valuable information that had not even been referred to in the summaries. There were two questions he wanted to raise. One was the question of bow mooring. Flight-Lieutenant Butcher had referred to two systems of mooring for non-rigids, one by a spar in the bow of the ship and the other by a horse shoe at the head of a headed mast to which the ship was secured at two points some distance aft. Trials of both these systems were carried out at Pulham and the horse shoe system was found the more satisfactory, but he did not think that was the conclusion that would finally be come to. One's natural instinct was that a ship should be moored by the bow. The spar method was developed at Kingsnorth as a side issue from the main function of the station—the design and construction of airships. The horse shoe method was developed at Barrow, where more men and more time were available. When competitive trials were carried out at Pulham they were made under the officer who carried out the trials at Barrow. The object of the horse shoe mast was to prevent rolling. The first system tried at Barrow consisted of securing the ship by a strut coming to a point low on the envelope, and considerable difficulty from rolling was experienced. It was to overcome the rolling the horse shoe was adopted. The principle of mooring rigid airships by the bow had been proved completely satisfactory, and he thought that as soon as the details of mooring non-rigid airships by the bow had been worked out completely, that was the method which would be adopted. It was the simpler of the two. Major Scott referred to the deposition of snow on the envelope and he mentioned that it adhered to the bow of the envelope. He (Wing-Commander Cave) had only seen snow deposited on the envelope on three occasions, and in every case it was confined to the tail of the envelope. It started on the part where they imagined the air-flow left the surface of the envelope. He wished to draw attention to the appendix of Major Scott's paper, which he understood was contributed largely by Flight-Lieutenant Rope, on the instability of airships in certain conditions. That was an appendix of considerable value.

There were two general conclusions which were important. One was the great importance of airmanship—if he might coin the word. Both these papers dealt with the practical handling of an airship apart from the construction and the methods of her flight. It had been his good fortune while in the Navy to be able to compare, in a primitive way, our Navy with those of other countries, and his opinion was that the respect in which our Service was most greatly superior to those of other countries was in seamanship—not in material, but in the method of handling the ships. The same thing was clearly seen in looking back over naval history. The same quality was shown by our own air officers in France, and the achievement of taking the R.34 to America and back was a very great achievement in the handling of an airship; how great only those who knew the mechanical difficulties and the unexpected problems that were encountered could appreciate. His own experience during the greater part of the war was with the design and construction of non-rigid airships, but he was impressed later, when it was possible for him to see what had been done in the handling of the airships, with the great increase in the practical utility of the ships, when the practical details of their handling had been properly developed. When one went round

the patrol stations one saw the small airships taken into places in woods and handled in extraordinary ways which at first sight would appear totally impossible. The handling of the airship played a most important part in their actual utility. Another point he wanted to make was the relative importance of improvement in construction and handling. The compulsory generosity of the Germans, both during and subsequent to the war, had resulted in our having the majority of their experience of 20 years in airship construction and two of practically their latest airships. The design of the R.38, being worked out at Cardington, would probably give equal performance. These ships were as regards lift capable of remarkable endurance. The only doubt was their reliability and the experience which was necessary for their practical use. Extensive long distance flying was necessary to determine what were the defects of present ships, what new characteristics or accessories were required, what weight would be justifiably expended in water recovery gear, and whether it was necessary to be able to burn hydrogen. In the construction of airships in the early part of the war great changes had to be made to meet requirements that could not be anticipated in the first design, and after they had some experience he had advocated as strongly as possible that each first ship should do very thorough tests before the construction of subsequent ships of the same class was proceeded with. It was not always possible, and the troubles that resulted were very considerable. Their activities would be restricted in future by reason of economy, but he was certain they were all anxious that the restriction should not fall on the practical use of the airships. The Society could best help in that direction by the preparation and discussion of papers on practical aeronautical subjects such as those they had had at that meeting.

Colonel GOLD said it was particularly interesting to the meteorologist to hear Major Scott appreciate so clearly the importance of meteorological information in connection with airship navigation. They were still near to the time when Major Scott made his great voyage across the Atlantic and they thoroughly appreciated how great that achievement was and could feel sure that it would fill a high place in history and rank with the greatest achievements of the human race in invention and exploration. Major Scott had emphasised the small distance across which one got high winds. If he would cast his mind back about a fortnight he would find that there was a westerly gale blowing at the surface over the whole extent from north of Lerwick, in the Shetlands, down to Brest, in the north of France, a distance of about 700 miles. If an airship had had to make a journey from Copenhagen to Edinburgh it would have drifted further east as it went further south, and instead of being the kind of curve they had seen from Malta to Pulham it would be a curve towards the Black Sea and back to Edinburgh. That was one of the worst kinds of weather that would have to be met if there was to be airship navigation across such latitudes as these. If, however, airship navigation were confined to latitudes south of Paris the same difficulties were unlikely to occur. It was in latitudes above 45° or 50° that these instances of really high winds or gales over extensive distances were likely to occur. In the winter months it was not unusual to get high winds from the Faroes down to the north coast of France. Major Scott mentioned the difficulty of getting the exact height of the airship above the ground, and he gave as a reason for wanting that height, that he wished to ascertain how high the barometer was at ground level with a view to ascertaining from that the direction in which the depression lay. Major Scott could obtain with sufficient accuracy the direction of the centre of the depression without knowing his height above the ground; if he found the wind at the height at which the airship was, that would give him a more accurate idea of the position of the centre of the depression than could be obtained by any means of measuring the barometer at the ground level from the airship. He understood Major Scott to say that inversions of temperature near the ground were more frequent in tropical regions; but in the Antarctic he thought Major Scott would find an inversion near the ground for about six months in the year and that in the tropics

there was no inversion near the ground on practically any day when there was sunshine, which meant on most days. Inversions near the ground in the tropics were confined—as they were largely in this latitude—to night. One occasionally got the temperature increasing as one went upward even in the daytime. A notable case occurred in France in February, 1917. The thermometer went down to three degrees at ground level and up to 18 or 20 degrees at 3,000 feet. One electrical phenomenon mentioned was very difficult for physicists to accept—the occurrence of a thunderstorm in the upper air with no indication of it at all on the wireless instruments on the ground. It was difficult to understand how there could be such a disturbance within the range of an instrument without affecting that instrument, in the absence of any conducting sheath to protect it. That there could be electrical disturbances at the tops of clouds without corresponding discharges on the ground was a well known fact. Flight-Lieutenant Butcher referred to a steady wind of 45 miles an hour with gusts up to 47 m.p.h. One's experience with anemogram records would not lead one to expect in this country a wind so steady as to have only a range of two miles an hour above the steady value. With a wind of 45 miles there would be usually gusts of 60 miles an hour. There were some places near the coast where the range would not be so big. The gusts might not go above 52 or 55 miles an hour, but he knew of no place where a steady wind of 45 miles per hour would rise in gusts to only 47 miles per hour. In connection with the mooring masts, was the landing effected in a high wind? The mast took the place of the landing sheds, and the ship could, presumably, be landed at the mast when the wind was too high for it to be landed in the sheds. Flight-Lieutenant Butcher gave them no information about the strength of the wind *at the time of landing* during these experiments although he said the wind, while the ship was moored to the mast, rose to 40 miles an hour. That was really the fundamental problem to be solved—to get the ship moored safely to the mast at the actual time when high winds were blowing.

Captain BYGRAVE said until recently his air experience had been confined to aeroplanes. He had the good fortune to take part in the 1,100 mile Handley Page Navigation Flight, to which Major Scott referred, and he then came to fairly definite conclusions as to the accuracy to be expected from bubble sextants and other navigational apparatus in the air. Those conclusions were greatly modified, however, when he took a 10-hour flight in the R.33. The steadiness of an airship came as a revelation and he found that a much higher degree of accuracy could be obtained than he expected. He was informed by the pilot that the day was more bumpy than usual and the conditions were therefore not particularly favourable for observations.

Drift could be taken with great precision, as practically no yaw was present, whilst in an aeroplane 10 to 15 degrees of yaw is often met with, and it is necessary to take the average of several drift observations. When over the sea it was usual to drop a flare in order to take the drift and time the "ground speed" as it floated astern. There would appear to be no special provision for taking this type of drift from the control car of airships, and he suggested that this matter should receive consideration in future designs.

The compass, of the Kelvin America type, was very steady in flight and the oscillations, which often amount to 10° in aeroplanes, were always confined to one or two degrees, and sometimes there was no apparent movement at all for a considerable period.

He took about a hundred observations with the R.A.E. bubble sextant of the sun, moon and stars. The wild oscillations of the bubble met with on aeroplanes, which may amount to as much as two degrees, was quite absent, and observations could be taken almost as easily as on the ground. For fore and aft observations the maximum error was 10 minutes of arc, and for athwartships 15 minutes of arc. By taking the mean of six observations it would be possible to reduce the error

to 5 minutes of arc. This would allow a position line to be drawn within five miles of its correct position, and at night when the stars are visible, the position could be absolutely fixed within eight miles. This is quite accurate for all practical purposes. Under these circumstances it did not appear to be necessary to use cloud horizons, which had proved unreliable as the top of a cloud layer may be of varying height, and in any case, having to alter the height of the airship, in the manner described by Major Scott, is a serious disadvantage. With regard to the use of the reflection of the sun in still water on the ground, this has such limited application that it is hardly worth serious consideration.

With regard to the reduction of sextant observations, the enclosed cabin affords great comfort, and the methods used at sea can easily be used. Owing to the speed of the airship, it is very necessary to reduce the time taken to a minimum, and a slide rule has been designed that allows the position line to be drawn on the map within five minutes of taking the sextant observation.

He thought that, with existing apparatus, there should be no difficulty in obtaining an accuracy comparable with that obtainable at sea in fast craft such as destroyers, and certainly three times the accuracy obtainable in heavier-than-air craft is to be expected.

With regard to future developments, Major Scott has emphasised the need of an instrument for indicating the true height of aircraft above the ground. He did not believe that any practical solution to this problem had yet been found. The reflection of sound, the capacity of the earth, the electrification of the atmosphere, and integrating vertical accelerometers offer interesting theoretical possibilities, but the application of any of these principles to an aircraft instrument is full of difficulty. Until some inventor provides the required instrument, all that can be done is to make the best of the present altimeter. The accuracy of the instrument could be improved by taking the temperature of the air at the height of the aircraft into consideration, and if the changes in the height of the barometer at ground level were communicated to the airship by wireless during a long flight, considerable accuracy could be obtained.

It is interesting to note that there is an alternative method of obtaining the speed and direction of the wind, when the height is not known, which does not demand a change of course such as described by Major Scott. This consists of timing the relative ground speeds at two different air speeds, and would appear to be particularly applicable to airships where such a large range of speed is available.

There is another point of particular interest in connection with airship navigation. During the day time, the measurement of the altitude of the sun gave a position line, and the most probable position of the aircraft on that line has to be determined from its dead reckoning position. If the azimuth of the sun could be taken at the same time as the altitude a definite fix could be obtained. On aeroplanes the magnitude of the accelerations seem to prevent azimuth observations being of sufficient accuracy to be of use, but the steadiness of airships and the absence of yaw would appear to bring such observations within the bounds of possibility. If the azimuth could be measured within one half of a degree, this would fix the position within 20 miles under favourable circumstances. This would be very valuable after flying some time above clouds or out to sea.

Mr. C. I. R. Campbell (Superintendent of Airship Design and Construction) said the lecturers marked a new advance as they dealt with specialist sides of aircraft. That was the direction in which papers should now branch out—the consideration in detail of important parts of the subject. In many papers it had been pointed out that on airship journeys it was very easy to get through or round the weather. The slides shown by Major Scott proved pretty conclusively that that was correct and would satisfy a great many doubters. As regarded the effect of adverse winds upon airship journeys, it was the case that over a short journey

the regularity in the running of an airship was bound to be poor. One essential advantage of an airship was her ability to go very long journeys, and over the greater part of such journeys she had greater choice both of position and direction of flight than an aeroplane, and if she had the meteorological information in good time she could do a great deal to dodge the weather or even to take advantage of it. When nearing, or just leaving, the landing ground she was fairly tied as to position, but even then she was not tied to direction. She could leave her post in any direction which the weather conditions rendered advisable. Under these conditions it would be rarely that an airship could not do her work with reasonable regularity. It was an essential point of an airship, compared with the ships we had been accustomed to, that her speed, while not so very much greater than the winds that were met, was much greater than the speed at which the depressions moved. While, therefore, the ordinary ship could not dodge depressions to any extent, but went plugging through them, an airship need not do so. Referring to Flight-Lieutenant Butcher's paper, he thought the great work of airships was going to be done with large rigids. They had the capacity and the power which the smaller ships had not, and a good mooring system was the only thing that made them possible in that sense. Experience showed that a large airship could not be handled on the ground, at least not as a commercial proceeding, in strong winds. The solution was not to come to ground, but to remain a hundred feet or more above it, and that was the solution offered by the mooring mast. Without that the development of airships could not go on, and too much importance could not be attached to it. They could now see their way through the design and construction difficulties of airships up to sizes considerably bigger than had yet been attempted. He did not mean that they could make the best possible airship of four or five million cubic feet, but they could make a thoroughly good serviceable one of high performance. The point that required attention all the time was mooring gear, and they must hope that the next year would see that in the forefront of development work.

Mr. J. R. PANNELL said he would have liked to discuss the early points in Major Scott's paper, but as they had not been read a note would be the most suitable method of adding a few remarks. With regard to superheating, in his limited experience of airship flying he found the ship practically the whole time pitched either nose up or nose down, due to superheating. It seemed an important question. The resistance of the airship was very appreciably increased by the angle at which she flew, and he thought that was a problem which would have an appreciable effect on speed when the solution was found. Major Scott suggested that electric storms were not a source of danger, as German airships had been struck on two occasions and had not been destroyed. In what way was it decided that the airship was struck, was there a spark from some part of the airship? Also two occasions was a very small number, and until a good deal more experience was gained he thought it must be considered that there was considerable danger. Major Scott remarked that he had only known snow to accumulate on the head of an airship; but in Commander Cave's experience it was deposited near the tail. This accumulation of snow gave an interesting insight into the flow round an airship. He remembered an occasion during a night flight of R.32 on which part of the apparatus lowered from the airship consisted of a streamline weight. Owing to the low temperature they were unable to continue the experiment and hauled in the weight; there was an accumulation of icicles on it, but only at the extreme nose. They were two inches or more in length, and there was no ice anywhere else.

With regard to wire mooring, he had hoped his colleague, Mr. Fraser, who had carried out a number of experiments with models of that system, would have been there, but unfortunately he was unable to be present. He hoped he would send a note to the Secretary on the subject. He would like to refer to Flight-Lieutenant Butcher's statement that experiments on the three-wire system had

been carried out in a wind tunnel at the N.P.L. Models were constructed and the displacements of the various parts measured under applied loads. These loads represented the wind forces calculated from experiments on airship models in the wind tunnel, and in that sense they were experiments carried out in the wind tunnel; but the displacements were actually measured on small models fixed to the floor. Flight-Lieutenant Butcher mentioned that difficulty was experienced in keeping R.26 moored steadily in "open-hawse" position. The system used on that occasion was N.P.L. modification number one. The need for greater stiffness under those conditions was confirmed soon after the full scale trials by experiments on models. The parallelogram system was recommended at a later date, as it promised to give considerably increased all-round stiffness. Shortly after a design was completed which was suitable for the later classes of airships. Here the base was 400 feet, and the ground left clear of all obstructions, and the system was, theoretically, more efficient than any of the 800ft. systems. Flight-Lieutenant Butcher thought a large ground area a disadvantage. That objection could scarcely prove serious with a 400ft. base. A hollow swivel at the mooring point would facilitate gassing and the maintenance of trim. With the 400ft. base the stern cleared all cables, and no trouble arose with the after guys.

It was of extreme importance that they should have an accurate record of the performance of all airships. Even with the obsolete ones it was very desirable that experiments should be carried out, and a ship marked for deletion could often be modified in a manner which would not be permissible for a ship on normal service. Nothing would advance the design of airships so much as information of that type.

In extension of his remarks at the reading of Major Scott's paper, he should like to add a few comments upon the early part of the paper which was omitted at the lecture. It appeared that the fundamental points dealt with in this portion of the paper would be more readily appreciated if the subject were treated in rather greater detail.

Under the heading "Aerostatics" the equation $PV = K$ is used to express Boyle's law, P being the pressure and K a constant; a few sentences later the same symbols are employed but they have different meanings.

The complete expression for lift of unit volume of a given sample of hydrogen (L) may be written

$$L = l_0 \times p \times B/B_0 \times T_0/T \quad . \quad . \quad . \quad . \quad (1)$$

where B and B_0 are values of the barometric pressure, T and T_0 values of absolute temperature, l the lift of unit volume of pure hydrogen, and p the percentage purity of the gas; the suffix o denotes normal values of pressure and temperature. The equation in the paper has been abbreviated to

$$L = (B/T) \times P \times K \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where P is the purity, so that the constant K now contains those quantities which are present in (1) and not in (2) ($l_0 T_0/B_0$) in addition to values "depending on the units used."

Similarly in dealing with the effect of superheating on a partially full gas bag, the volume of the gas (V) will be given by

$$V = V_0 \times B_0/B \times T_1/T_0 \quad . \quad . \quad . \quad . \quad (3)$$

where T_1 is the temperature of the gas. This formula is given in the paper as

$$V = (T_1/B) \times K \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and K must now contain $V_0 B_0/T_0$.

The lift (L_v) of this volume of gas (V) under the new conditions will be given by

$$L_v = L_0 \times V \times B/B_0 \times T_0/T_2 \quad . \quad . \quad . \quad . \quad (5)$$

where T_2 is the temperature of the air, or as given by Major Scott

$$L = (B/T_2) \times K \times V \quad . \quad . \quad . \quad . \quad . \quad (6)$$

where K includes $L_0 T_0/B_0$; therefore K in equation (2) is equal to K in equation (6) except that in the former there is the lift of unit volume of pure hydrogen, and in the latter of a certain sample of hydrogen. Substituting for V in (5) we get, for the total lift after superheating

$$L_v = L_0 V_0 \times T_1/T_2 \quad . \quad . \quad . \quad . \quad . \quad (7)$$

or in the form used by Major Scott

$$L = (T_1/T_2) K \quad . \quad . \quad . \quad . \quad . \quad (8)$$

It will be observed that the increase of lift in a partially filled gas bag is proportional to the degree of superheat, and independent of changes in the barometric pressure. The physical explanation of this is of course that increase in density of the air displaced is compensated by decrease in its volume. The effect of superheating is due to change of volume and there would be no appreciable change in lift due to superheating a bag full of gas. Changes of density of the gas have been neglected throughout.

The value of the section dealing with aerodynamics would be increased for those with limited knowledge of the subject, if the methods of deriving the relation of the various quantities on change of size were given in greater detail.

Commander F. L. M. BOOTHBY did not think anyone could say what should be done when one was caught in a thunderstorm. It would be very useful to pilots to know how to proceed. He knew of a German pilot who was caught in three thunderstorms. He came down and got through all right. Another pilot had been in ships which were actually struck on two occasions, both times while the aerial was down. Did the aerial save her by causing the flash to take place well away from the hull, or would she never have been struck had the aerial been hauled in? The exhaust gases from the motors were good conductors, and in view of that it would be interesting to know whether it was better to stop the motors or run them. If a committee could be got together to go into the best action to take in a thunderstorm something useful might be evolved. He thought Flight-Lieutenant Butcher touched very little on the more important side of the mooring question—the work over water. Unless an airship always landed light, ashore, there must be a landing party to catch the cars, but commercial airships would carry all the load possible and they might have to land heavy. In that case, unless a landing party was used they must come down over water. He thought they would get back to the original scheme evolved by Admiral Bacon for Naval Airship No. 1—that airships should moor over water and alight on it, being handled by tugs, not men. This could be applied to landing grounds near London. A place like Brooklands could easily be flooded, and three feet of water would be enough.

Flight-Lieutenant PRITCHARD said it was, of course, during long pioneer flights, rather than on a series of short flights round a home base, that new knowledge connected with airship pilotage was most rapidly obtained. To demonstrate the problems which an airship captain had to solve, he proposed to take a concrete illustration from the trans-Atlantic flight of R.34, on which he was sent by the Admiralty as a kind of tame spy to collect and record technical data. He took a number of photographs during the flight, and of these, two were particularly interesting as showing an important part of the work which few realise. (Two photos of Major Scott on the R.34 were then shown, one with a worried and the other with a pleased expression.) It might be called original research at a moment's notice. The problem under consideration was the excessive superheating over the ice floes of Newfoundland. This was the first time that an airship had flown over an ice floe and encountered the extraordinarily marked

inversion temperature effect which, under certain conditions, was experienced. If Major Scott had not solved this new and unexpected problem correctly, R.34 would, on the ensuing night, have become so heavy, due to the dissipation of false lift, that it would have been necessary to burn so much petrol to keep her in the air that she would not have been able to reach her landing ground in America. He hoped Major Scott would forgive him for showing the slides. They were taken without his knowledge and he knew he secretly wished they were destroyed. It was comparatively easy to fly a high performance ship over routes which did not tax her endurance to the uttermost, but it was when piloting a comparatively obsolete ship like R.34, possessing too small a range and too slow a speed to fly the 3,000 odd miles from Scotland to New York in the teeth of a prevailing wind, that true skill in piloting came to the fore.

He would now refer to a few of the technical points paised by Major Scott. During a normal long distance flight, superheating reduced the paper performance of a present day rigid by as much as 10 per cent., due to the large changes in buoyancy which necessitated flying the ship nose down for the majority of the day and nose up during most of the night. Under normal weather conditions it took about three hours to obtain maximum superheating during the day. If this lag could be materially increased, most favourable results would be obtained. This could be effected in two ways—by increasing the size of the ship, which means that the ratio superficial area/volume decreased, and by improving the outer cover so that less heat passed through a given area in unit time. If this superheating lag could be increased to about nine hours instead of the present three hours, the maximum superheating would be greatly decreased and a much more equable temperature would be maintained. In this way the practical performance would more nearly approach the paper performance. The mooring problems were of extreme importance and could not be too strongly emphasised. At present the performance of an airship was far in advance of the ground organisation. Although it was most important from the hull designer's point of view to know that hull design advanced more than anything else it was not a sound proposition. Ground organisation and research should be pushed ahead to catch up to the hull designer.

Major SCOTT, replying to the discussion, said the case he had taken in regard to the question of snow was the R.9. The deposit was on the forward end of the parallel portion. It depended very much on the shape of the ship. With a good streamlined shape it may deposit on the tail. It was the wet snow that stuck, and the correct thing to do was to get into the dry snow. He agreed with Colonel Gold that in the case of a gale, such as he described, it would be difficult to fly in the Atlantic or anywhere on the northern side of Europe. Most of the cases he (Major Scott) had considered were over the Mediterranean and nearer the tropics, which, after all, was a trade route. Even in that case, with good warning, an airship coming from the Mediterranean could have got through it all right. The height of the barometer on the ground was really not so much to give the pilot the direction in which the centre of the depression was as to enable one to know how long it would take him to get there. He wanted to cut across the centre of it as quickly as possible. The idea was to be able to judge whether one was going in the right direction to strike the centre of the depression. The Italian pilots had experienced, in the Mediterranean, a great deal of the inversion of temperature. They almost invariably get it during certain parts of the day. He agreed with Captain Bygrave that some method of taking the tail drift was necessary. Something to enable this to be done should be put right in the tail of the ship. He thought it had been considered. He agreed that ground organisation required particular attention at the moment. In the German airships which were caught in thunderstorms the wireless weights were burnt off. The bow was struck in one case and the bow girders were fused together. He thought the motors should be kept running in a thunderstorm, because of the

disturbed state of the air, regardless of whether it was the best thing or not from an electrical point of view. Alteration in height was the only thing he knew of to get out of a storm.

Flight-Lieutenant BUTCHER, also replying to the discussion, said the question of the velocity of the wind at the time of mooring was dealt with in the full text of the paper. The ship landed the first time in a wind of between 7 and 10 miles an hour, and as the ship was of an old type the mid-ship car was taken off, reducing her speed to 25 miles an hour to give more disposable lift. As they could not conduct landing experiments in winds of over 20 miles an hour, it was decided to carry out tests by easing her out on the mooring wire and hauling her back to the coupling. This was accomplished in winds of 28 miles an hour without damage. He had not much experience of mooring over the sea, but it had great possibilities, and he thought it would be worth somebody's while to bring out a paper on it.

A vote of thanks to the Chairman was proposed by Mr. A. E. BERRIMAN, who said the warmth of their reception of the former would be increased on account of the subject for which he had just expressed his interest.

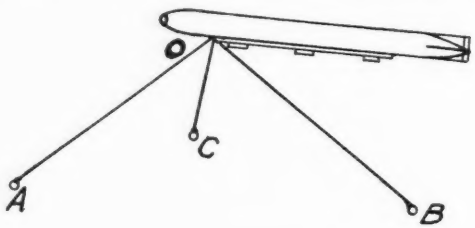
NOTE ON THE MOORING OF AIRSHIPS BY "FREE" WIRE SYSTEMS.

BY R. A. FRAZER, B.A., B.SC., and L. F. G. SIMMONS, B.A., A.R.C.SC.

In his recent lecture on "Airship Mooring and Handling," Captain Butcher refers to certain experiments carried out with the use of models in connection with three-wire mooring. It is, perhaps, useful to add some further details of these special experiments, which were conducted at the National Physical Laboratory.

Mention was made by Captain Butcher of the original or "fixed" three-wire system (see Fig. 1), which originated from the emergency mooring of R.9. Its defects lie in the occasional slackening and subsequent impulsive tightening of one or more of the mooring cables when the airship is riding in gusty weather. In the particular modifications introduced by the N.P.L., breakdown due to this contingency is eliminated.

The Mooring of Airships by Free Cable Systems.



Fixed Three Cable System.

FIG. 1.

A B C denote fixed bollards.

Certain characteristic features of the "free" systems serve to differentiate them from other systems of mooring. In particular, they permit of the airship swivel moving over a geometrically defined surface and displacing to new positions as the wind varies in speed or direction, without loss of tension in any of the mooring members and without undue loss of altitude. In order to secure this type of constraint, the swivel is attached to a non-redundant arrangement of mooring cables, in which the cables pass over suitably disposed blocks or connect to fixed bollards or moving splicing rings. The distance through which the swivel will displace under given alterations in the wind varies with the design of the mooring system, and the system possesses a greater or less degree of "stiffness" according as these swivel displacements are small or marked. Thus, in their general conception, these "free" systems are not necessarily confined to the use of three main mooring cables arranged equilaterally.

In order to lay out designs suitable for prescribed classes of airship, progressive experiments were carried out with scale models of a number of systems. It was found convenient to represent the cables by lengths of fine silk fishing cord, and to reproduce the blocks as small light metal pulleys mounted on point bearings. Information from wind-channel experiments was utilised indirectly by

applying at the swivel loads equivalent to the predicted forces on the airship due to typical conditions of trim and representative wind speeds and wind directions. Suitable allowance was also made for static reserve lift. By measurements of the displacements undergone by the swivel under such loads, sets of " displacement-loci " were determined, each curve of which exhibited the positions of the swivels appropriate to steady winds of given speed blowing from different quarters. These displacement curves were found to be in general not plane contours. A direct comparison of the " stiffness " between two systems was possible by comparing the relative sizes of corresponding displacement-loci in the two systems. In addition, the effects of lateral gusts on two systems were compared by analogous methods.

An illustration of a typical " free " cable system, comprising four mooring cables, is given in Fig. 2. This system was investigated in connection with mooring of 23 class airships.

The Mooring of Airships by Free Cable Systems.

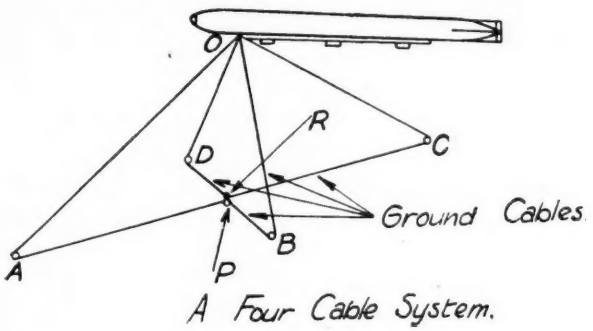


FIG. 2.

A B C D denote swivelling pulleys attached to fixed bollards.
P denotes a pulley fixed to a splicing ring.
R denotes a splicing ring.

In the above the base points A B C D are arranged at the corners of a square. Two of the mooring cables are continuous through two of the fixed pulleys, A B, and the moving block P; the remaining two mooring cables pass over fixed pulleys C D, and are spliced at the ring R. It will be seen that by use of a cable linkage of this type the swivel O admits of continuous displacement over a wide range, during which every cable is maintained in tension.

In Fig. 3 a characteristic displacement is given, representing the locus of projected positions assumed by the swivel in this system when the airship is moored out under zero reserve lift in steady winds of 60 miles per hour at an upward angle of inclination 6°.

For three selected points of this locus (indicated by small numbered circles) the corresponding wind directions are shown by the aid of arrows. Points similarly numbered, lying off this locus, determine the further lateral displacements of the swivel when the airship is struck by a representative gust of force two tons on either bow. Reference to Fig. 3 illustrates that the amplitude of the displacements due to gusts of given magnitude may vary with the quarter from which the wind is blowing.

It is of importance to observe that when the reserve lift of an airship is assumed to be zero (case of static equilibrium), a displacement curve is dependent only upon the angle of trim and not upon the wind speed. In general, at each

point of a displacement locus the resultant force on the swivel coincides in direction with the normal to the " swivel-surface " which contains all possible positions of the swivel. A particular locus is, in fact, defined not by *magnitude* of the resultant force but by its *direction;* when static lift is absent and the trim angle constant the force direction—and consequently the locus—is independent of wind speed.

The Mooring of Airships by Free Cable Systems.

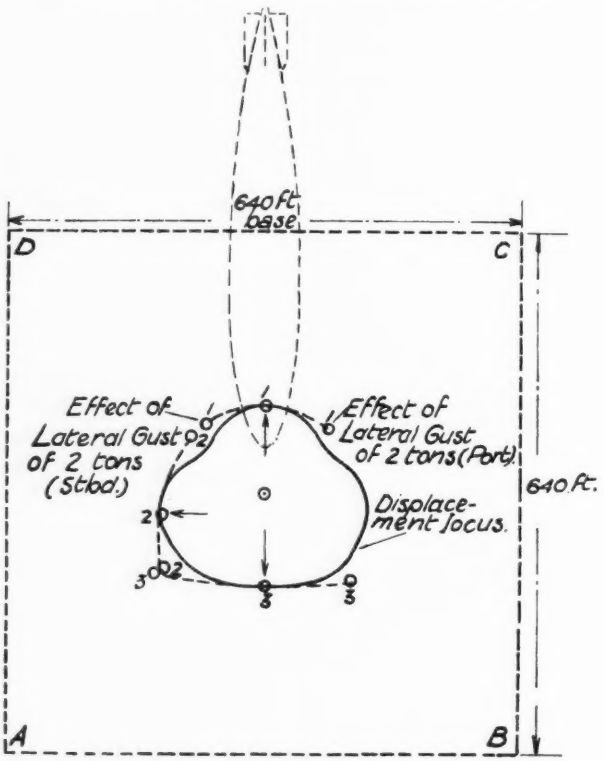


FIG. 3.

Projected displacements of 23 Class airships when moored out on four cables in steady and gusty winds of 60 m.p.h.
Angle of trim, 6° nose up. Reserve lift, zero.

From this viewpoint it is preferable to regard a set of displacement curves as defining loci along which the normal directions to the " swivel-surface " are prescribed. Once a set of these curves are available, it is at once possible to predict the position of the airship for given circumstances of mooring by calculating the direction of the resultant of the static and aerodynamic forces acting on the airship.

Reference was made by Captain Butcher to a number of representative types in which three main mooring cables are employed and an 800ft. equilateral ground base.

System Mark I.

The first type, designated as Mark I. (see Fig. 4), was developed originally in connection with full-scale mooring experiments on R.26; it was also employed for R.34 at Mineola.

The Mooring of Airships by Free Cable Systems.

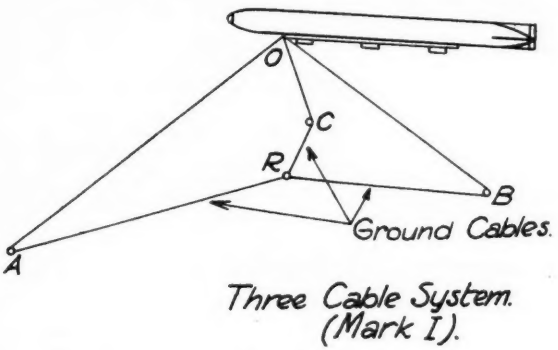


FIG. 4.

A B C denote swivelling pulleys attached to fixed bollards.
R denotes a splicing ring.

Displacement curves due to steady and gusty winds were derived for this system; these naturally showed a symmetry about the three median planes passing through the vortices of the ground base. From the experiments on the model it was concluded that better lateral stability was to be expected when the airship was riding across a base line than when it was riding over one of the vortices A B C. This conclusion was in agreement with observations on R.26 during the full-scale experiments.

System Mark IV.

An all-round improved "stiffness" was to be expected from subsequent measurements of a model system in which the central ground ring of the previous anchorage was replaced by a parallelogram cable linkage. A perspective drawing of this system (Mark IV.) is given in Fig. 5. Each of the three mooring cables is here attached to a corner of the parallellogram, whilst a short strop length connects a fixed bollard (D) to the fourth corner.

It was found that the "stiffness" could be varied to conform with particular requirements by judicious adjustment of the lengths of the main cables, the length of the strop and the dimensions of the parallelogram.

System Mark V.

A system (see Fig. 6) more particularly suited to the demands of airships of the 33 class is described below. It offers a number of important improvements, in that it is both more compact in dimensions than the earlier systems and presents a steeper pyramidal grouping of the mooring cables in the locality of the swivel. The advantage in this latter feature lies in the elimination of any possibility of these cables fouling the forward car when the airship acquires a severe upward angle of pitch. It also appears from the experiments on models of this system

that a considerably higher degree of stiffness can be secured than with the previous types of anchorage.

The system (Mark V.) may be specified broadly as comprising a short pyramid of three equal " ship cables," Oa, Ob, Oc, whose lower extremities are attached to a " continuous " length of cable running through ground pulleys A B C at the apices of a 400ft. equilateral ground base. A symmetry exists in the grouping of the cables in the " no wind " position with regard to a vertical axis through the swivel, the plan of the continuous cable in this position resembling a three-point star. Thus for all positions of the airship the cables are freely sup-

The Mooring of Airships by Free Cable Systems.

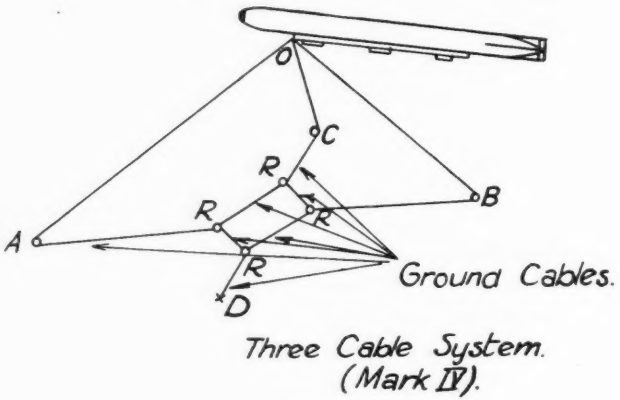


FIG. 5.

R denotes splicing rings.
D denotes a bollard fixed along the external bisector of A B.

ported above the ground—or above the level of the water in the case where the airship is moored over water—leaving the handling space clear of obstruction. The elimination of damping forces, introduced in earlier systems by frictional forces between certain cables and the ground, is not regarded as serious, since such forces are estimated to be small in comparison with the wind forces operating. On the other hand, a distinct advantage results from keeping the system wholly clear of the ground, since the cables are saved from any deterioration which the ground friction might entail. Should it be found expedient in practice to introduce further friction, auxiliary braking methods could be devised.

Certain practical facilities are, it is thought, likely to accrue, without impairing the efficiency, from the use of short strops attached to the bollards A B C, for carrying the ground pulleys. It has been suggested by the Airship Department that the " ship cables " forming the upper pyramid could conveniently be carried by the airship during flight and lowered into position for purposes of making fast. Under such circumstances a small adjustment provided by the strops would materially assist during the operations entailed in attaching the ship cables to the splicing rings in the continuous cable.

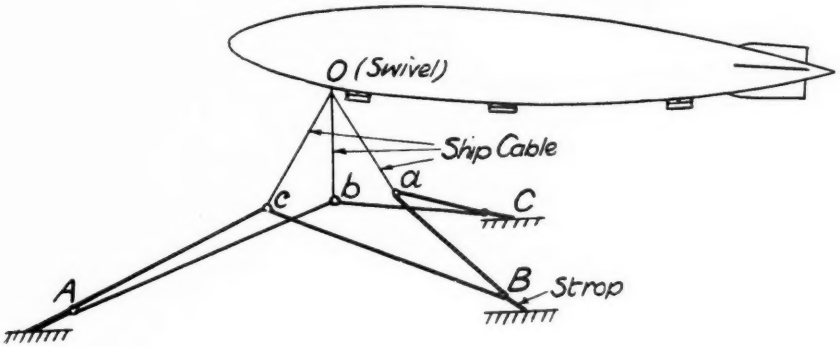
With choice of cables of certain standard lengths the system may be made markedly stiffer than the earlier systems as regards both down-wind displacements and transverse displacements due to gusts. Any increase in these lengths lends additional freedom to the system; whilst reduction of length introduces further stiffness.

Loss of altitude resulting from displacement of the swivel is confined within

reasonable limits; with the airship in equilibrium and normal trim this loss amounts to less than 5 per cent. of the initial altitude of the swivel in the "no wind" position. The initial altitude is, however, readily susceptible to small changes in the lengths of the strops, a 10ft. strop producing a 17 per cent. increase of altitude in the "no wind" position.

In order to specify the cable sizes for any system, information was required relating to the maximum tensions likely to arise in practice. Determinations were consequently made of the cable tensions corresponding with the worst conditions. These special investigations were expedited, in the case of the Mark V. system,

The Mooring of Airships by Free Cable Systems.



System Mark V

FIG. 6.

A B C denote swivelling pulleys attached to fixed bollards.
a b c denote splicing rings.

by the use of a small tensionmeter, designed to record accurately tensions of the order 2-3lbs.; and this also enabled a more detailed exploration to be undertaken of the tensions in the separate cables.

Captain Butcher referred to certain difficulties which were experienced during the trials of System Mark I. in connection with the fouling between mooring cables and the handling guys and other auxiliary ropes carrying compensating ballast at the stern. With use of the 400ft. base, to which System Mark II. is designed, no such trouble need arise.

In conclusion, it should, however, be emphasised that with such mooring systems, as with others, efficient and convenient ballasting arrangements are essential for satisfactory maintenance of trim. A hollow type of swivel would materially assist in such gassing and ballasting operations.

DEVELOPMENT OF GIANT AIRCRAFT IN GERMANY.

I.

Introduction.

In attempting to survey the growth and progress of the "Giant" aeroplane in Germany, it is first of all necessary to review the circumstances and conditions which determined and necessitated the direction of effort in this direction, and secondly, to indicate roughly the accessory circumstances peculiar to the conditions of the Central Empires during the war at the period when giant aircraft first began to appear, and to distinguish if possible the influence of these circumstances where they bear on development in a manner either conflicting or diverse from the conditions appertaining in Entente countries.

Such a preliminary survey is absolutely necessary in order to disabuse the mind of its natural tendency to compare the completed individual German giant aeroplane with its corresponding Entente type; and at the same time to prepare one of the various confusing and unexplained peculiarities which must tend to mislead, if the ruling circumstances are not first made clear.

In order to eliminate from our survey all unessential circumstances which might tend to confuse the main issue, we propose to treat the subject as a comprehensive whole, avoiding wherever possible reference to the minor peculiarities in constitution, design, or performance, of any one individual machine. So delicate a compromise is the modern aeroplane that any other method of examination must necessarily be misleading, and indeed in this way only is it possible to sift from the mass of information available those essential and fundamental facts which it is our object to discover and without a clear impression of which it is impossible to formulate a conclusion, or turn to profit the accumulation of experience represented by the various examples of German giant aircraft.

Reasons for the War Development of Giant Aircraft in Germany.

The progress of any new development is primarily due to competition. In a state of war the normal conditions of competition become accentuated in the struggle for supremacy in every branch of war activity.

In the early stages of the war, both the Entente and the Central Empires were in parallel circumstances as regards their resources in aeroplanes and seaplanes. Only single-engined machines were at this time available for war purposes, and in some respects the aeroplane considered as a "glider" was in advance of its engine.

The first effects of intensive war competition was naturally to be expected in the shape of improvements in the petrol motor.

Under war stimulus the improvement of the aeroplane motor was rapid, and is to be traced in the continually increasing horse-power of aeroplane engines. Due to this initial development the aeroplane, followed by the seaplane, rapidly became factors of importance in the world war. The influence of the aeroplane motor on aeroplane development will be again referred to later. It is important, however, at this stage to note that engine improvements were at this time of vital importance. Up till 1915 when the military situation began to become stabilised, the ordinary one and two-seater aeroplane and seaplane were sufficient to meet immediate requirements in so far as the state of aircraft development permitted.

Bombing was not at this time seriously considered on the army fronts, but the early successes of the Zeppelins had opened the eyes of the Central Empires to the possibility of aerial attack on rival capitals. The possession of Belgium as a suitable "taking off" ground for attacks on London and other towns made the prospect still more alluring. Germany immediately commenced to experiment with and to construct large bombing aeroplanes. They had at this time no particular incentive in so far as the enlargement of seaplanes was concerned, in view of the fact that the naval Zeppelins were far in advance of her heavier-than-air craft. The development of the German "giant" seaplane was, in consequence, of a much later date than in the case of the aeroplane. Here we notice the first disparity in the aeronautical situation as between the Entente and Germany. The development of Allied aeroplanes and seaplanes took place concurrently, with the seaplane, in so far as size is concerned, ahead of the aeroplane. In Germany the circumstances were reversed, and the seaplane has followed the lead of the aeroplane. In consequence the large or "giant" German seaplanes may be expected to bear a very close relationship to the German "giant" aeroplanes.

The political and strategical importance of aerial bombing having been early made clear to the Central Powers, it was only natural that Germany should at once commence to provide herself with "heavy bombing machines" possessing a long "flight range," and that such "bombing machines" should, under the stress of competition, rapidly become "giant" machines. The Allies had no such definite incentive, and could therefore not be expected to expend the same energy in this direction.

Germany for these reasons was, and still is, considerably in advance of Entente countries as regards experiment and research in the sphere of giant aircraft.

Since the construction of giant aircraft in Germany was directed principally to the purpose of long distance bombing, for which purpose the geographical situation was well suited, we may expect to see further divergences from Entente practices, in that, while the German product was designed almost exclusively for one particular purpose, the Entente bombing and "giant" machines on the other hand were multi-functioned. In a word, the German giant aeroplanes were primarily of strategic value, the Entente aeroplanes of tactical value. This again must be expected to produce a certain difference in type, which will most probably be shown in the minor details such as "handiness" and "maintenance" no less than in the size or overall dimensions. These circumstances are slightly different in regard to the seaplane, where German development in any case commenced at a later date; but the same influence may be expected to make itself felt in that the German giant seaplane is naturally founded on the experience gained with previously constructed land aeroplanes. This last circumstance is of some importance and to it must be attributed the fact that German giant aircraft constructors are in the majority of cases the designers of both seaplanes and aeroplanes. Apart from details we may expect then to find the design and conception of giant seaplanes and aeroplanes very much the same.

The effect of the blockade must also be expected to exert its influence on aircraft construction, and more particularly in the case of giant machines whose dimensions called for unusual "lengths" of wood for the manufacture of wing spars, etc. In short, the shortage of materials undoubtedly influenced the construction of German aeroplanes very considerably, and this constitutes yet another factor which must be reckoned with in comparing the rival machines of both sides.

Moreover, it will serve in several places to explain the reason for various departures in design and construction from what under ordinary circumstances would be the standard and simpler method. The immediate effect of a shortage of raw materials must be expected to exercise an adverse effect on construction;

but it is by no means certain that in the long run the ultimate effects of shortage may not have its compensations in that such a state of affairs is in itself an incentive to invention. In any case, here we may again expect a sharp divergence from the general practice in Entente countries where shortage of materials was undoubtedly felt, but never very acutely, or to anything like the same extent as in Germany.

All these factors then must be borne in mind while assessing the merits and demerits of the machines under review; and it will be necessary to exercise a good deal of care in passing judgment on individual peculiarities in design, lest the cause be forgotten in considering only the effect, and a wrong estimate of value be arrived at.

There is one other minor consideration and yet one of some importance as exercising an influence on all machines and types. A general reference has already been made to aeroplane engine development, and it will now be necessary to examine this a little more carefully before embarking on the general survey of actual machines.

With the development of the rotary engines we are not here concerned, since their extravagant consumption of fuel renders them unsuitable for long range giant aircraft. The development of giant aircraft was, however, necessarily dependent on the available engine power. The need for increased engine power so far as Entente countries were concerned resulted in the early adoption of the V-type twelve-cylinder stationary motor. Germany, on the contrary, chiefly it appears owing to the conservative attitude of the powerful Daimler-Mercedes combination, who considered that the standard single line, six-cylinder stationary motor could be made to give all the power required, did not commence to develop the V-type engine until considerably later. Too late in fact to allow of such motors taking an active part in the war.

The result of this circumstance is twofold. In the first place, the most powerful German engine units were not as powerful as those of the Allies. Consequently the necessity for providing more and more power for giant machines drove the German designers into adopting designs suitable for a number of motors at an earlier date than was necessary in Allied countries. There is no doubt that this constituted a grave disadvantage; on the other hand, however, the German six-cylinder motors were considerably more economical in relative fuel consumption than their more powerful V-type rivals. The importance of fuel economy in relation to long range giant machines needs no emphasis, but nevertheless this combination of circumstances is of vital importance and must be given full consideration when comparing the German types with the corresponding Allied machines.

In view of the far-reaching influence of these circumstances, it would seem best to avoid as far as possible in our general survey any reference to the individual peculiarities of single machines, avoiding thereby the possibility of giving too much consideration to the special features of any one example, which may rivet attention by reason of its novelty in comparison to Entente experience, but whose very originality may be due to the accident of circumstance rather than to deliberate intention. For this reason it will be best to avoid as far as possible any attempt at comparison as between Allied and German productions, and to confine ourselves to an impartial examination of all the available facts, with a view to extracting therefrom such information as may be of service to the Allied cause.

It is proposed, therefore, to divide the remainder of this review into three portions. In the first part we shall survey the general lines along which development has proceeded, with a view to classifying in distinct "types" the various machines under consideration, and at the same time endeavour to locate that line of advance along which further progress can best take place. In the second portion, under the heading of "Minor features in German Giant Aircraft," we

shall, assisted by the previous investigation in "types" and forewarned by the various circumstances discussed in the introduction, make an examination of the collective minor features of the machines under review, avoiding as far as possible any discussion on the constructional details of any one machine.

In the last part of the survey we shall endeavour to draw some definite conclusion, not as to which is the "best" machine, but as to which type of design as dictated by sound fundamental principles is best suited for progressive development; afterwards pointing, if possible, from the results of German experience, to the means whereby such development can be achieved in practice, and finally turning these conclusions to our own advantage by indicating in outline the "short cut" to military and commercial supremacy in giant aircraft.

II.

DEFINITE LINES OF DEVELOPMENT AND PRINCIPLES INVOLVED.

It is possible to distinguish three important and distinct lines of advance towards the development of German giant aircraft, whether aeroplanes or seaplanes.

(1) "Type A."—Enlargement of aircraft by the increase of power brought about by multiplication in the number of motors; which motors are arranged as conveniently as possible in the wings (*i.e.*, not massed on the centre line, in the fuselage or body).

Examples.—A.E.G., Gotha, Albatross, Staakener (aeroplanes and seaplanes), Friederichshafen (A. and S.) Dornier.

(2) "Type B."—Enlargement of aircraft by the increase of power brought about by multiplication in the number of motors; which motors are arranged in the central fuselage or body and designed to drive one or more propellers through the medium of shafts or gearing.

Examples.—D.F.W., Siemens-Schuckert-Linke-Hoffman.

(3) "Type C."—Radical departure from precedence in design, aiming at a greater all-round efficiency, irrespective of the arrangement of motors or power installation.

Examples.—Junker, Fokker (Limousine) Siemen-Schukert (new type).

It should be noted—and so far as German aircraft are concerned observed with emphasis—that the enlargement of aircraft has been undertaken with the very definite objective of increasing the useful load, and hence the military and civil value of individual aircraft; and for no other reason.

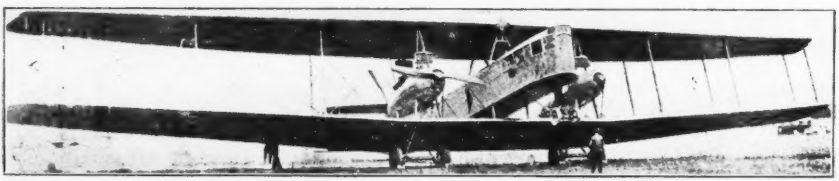
Advantages and Disadvantages of Type A.

Giant aircraft in which two or more motors are arranged in the wings, or at least away from the centre line, make up the bulk of large aircraft in Germany, as in the Entente countries. They have the advantage that the designer undertakes no special experimental work, is assisted by an accumulation of previous experience in the same type, and faces no constructional difficulties. Standard engines and simple fittings without any special or complicated devices are employed, for which reasons construction is comparatively simple and cheap. This form of construction, *i.e.*, with the motors disposed in the wings, simplifies rather than complicates design, and allows of a certain small reduction in the proportionate weight of the wing structure. For the same reason it permits of the span

being slightly further increased without a disproportionate growth in wing structure weight. The arrangement of the motors in the wings facilitates the design of the landing carriage or floats—a point of ever-growing importance with increasing size. For these reasons, and indeed naturally, the development of large aircraft on these lines has been more marked than on any other basis. Unfortunately, however, machines of this class possess all the vices of their virtues. They are, generally speaking, clumsy, and owing to the fact that they adhere too closely to precedent, almost invariably present an immense area of passive head resistance. This point needs no special emphasis, since Entente machines of this type, like the German representatives, are notorious and conspicuous for a multiplication of struts, stays, king-posts, and other "parasite" resistances. This is so much the case that in many instances designers of this type of aircraft base their main claims for merit, not on the increase of useful load obtained, but on the "reliability" of the machine in flight. In the case of two-engined machines there is no longer any doubt that claims for greater "reliability" are devoid of any real foundation, and indeed this must necessarily be the case in any heavier-than-air craft carrying a normal load, where the number of motors does not exceed three. (By "reliability" is meant greater immunity from a forced descent, due to the failure of a motor.)

FIG. 1.

A Type "A" machine (German).
"Staaken" or Zeppelin Giant.



Note the exposed engine nacelles, the innumerable struts, stays, etc., all forming "passive resistance."

Beyond the slight constructional advantages already mentioned, and the possibility of obtaining a good "view" for the pilot and observer with more or less unobstructed accommodation for passengers, bombs and cargo in the central fuselage, the further development of this class or type of machine offers very little prospect of real success. Indeed, the larger existing machines—at any rate of German origin—are already beginning to demonstrate such obvious defects and inefficiency as to render continuance on the same lines altogether unprofitable.

The decline of effort in the direction of progress with this type of design is apparent in Germany as in other countries, and can be seen by the falling off in the number of firms undertaking the design of this description of large aircraft. It has, in fact, become generally recognsed that efficiency cannot be obtained on these lines, without radical departure from the design of existing Type "A" machines.

In a word, the slight advantage in structure weight which is perhaps the feature of this type is more than counterbalanced by the additional "passive" and "parasite" head resistance which characterises such machines. Moreover, the hopes of some designers—who use the same type of design with four motors, placed back to back in pairs—have not in practice been realised, the result being responsible for a still further slight loss of efficiency, which is not sufficiently accounted for by a slight balance in favour of greater "reliability."

Nevertheless, this type of machine, owing to its simplicity of design and construction, has, considered from a purely military point of view, many desirable features, not the least of which is its suitability for rapid production.

Advantages and Disadvantages of Type " B."

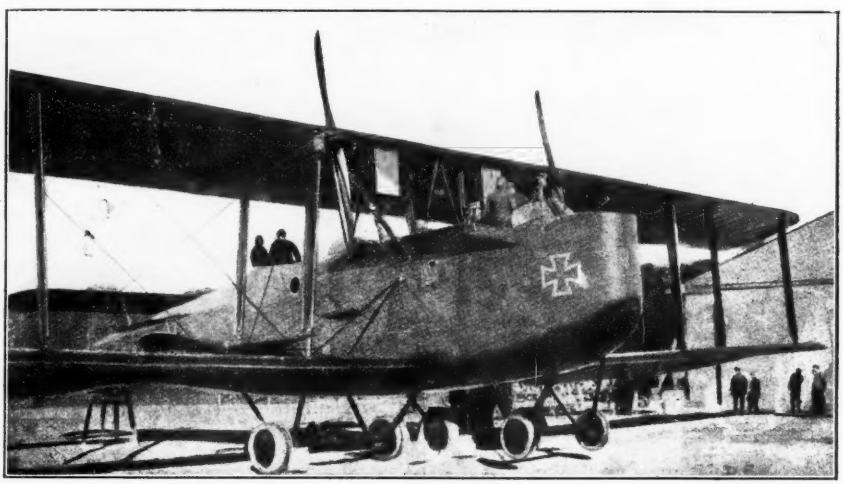
Giant aircraft in which two or more motors are grouped in the central fuselage, driving one or more propellers through gearing or shafts.

The development of this type is undoubtedly largely due to the realisation of the inherent defects in Type " A " aircraft (*i.e.*, the disproportionate increase in passive head resistance), and to a certain extent to the demands of civil aviation for greater reliability. It is for this latter reason, perhaps, that machines of this class have only comparatively recently come into existence.

The outstanding advantages of the type then are:—Firstly, a certain reduction of unnecessary head resistance; and secondly, a gain in " reliability," which may be perhaps still further enhanced by the fact that motors so disposed (*i.e.*, enclosed in the main fuselage) are readily accessible in flight. This latter consideration, whatever its actual merits, is one carrying considerable weight in so far as commercial undertakings are concerned; and this in spite of the fact that the placing of the motors in the fuselage must necessarily to some extent prejudice both the comfort of passengers and the space available for cargo.

FIG. 2.

An example of a German Type " B " machine.



Note the absence of exposed engine units, and the generally " clean " appearance of the machine, denoting a reduced head resistance as compared with Type " A " designs.

There is moreover—although at first sight this appears improbable—an actual gain, due to the employment of gears or gear drives, in that the propeller revolutions can be arranged for maximum efficiency.

(The Germans were apparently early aware of the advantages of gearing, despite the extra weight involved, and even in twin-engined " bombers " of now obsolete type had in some cases fitted gearing between engines and propeller at

a sacrifice in weight of about 16lbs. per h.p., but with a gain in efficiency and "performance.")

The advantages of the type then may be briefly summed up as follows:—

(1) "Reliability" enhanced by the accessibility of the motors.

(2) Reduction in "head resistance."

These two items are to a large extent counterbalanced by the overcrowding of the fuselage with motors, etc., and the constructional disadvantage of having all the weight massed in the centre of the machine. This latter evil, however, is to some extent mitigated by the generally better conditions for adequate lateral control due to a reduced transverse moment of inertia. The massing of the weights in the centre line must however impose a smaller limit on the possible span breadth than in the case of Type "A" machines, and is therefore a serious and fundamental disadvantage in so far as *maximum* size is concerned.

At present, however, the "performance" in relation to the speed of machines of this type shows considerable promise by comparison with Type "A," and if the gears and propeller transmission arrangements should prove "commercially" satisfactory, a certain degree of temporary success and popularity is to be anticipated.

It is doubtful, however, if the type as represented by existing examples can be regarded as a satisfactory basis for important development.

In so far as the arrangements for the gearing of the multiple motors is concerned, there is a large variation within the type, the number of propellers varying from one to four, with a disposition either central as with one propeller, or in the case of four, arranged in the wings. In the former case the disadvantages from a purely military point of view are obvious, as it is almost impossible to obtain a good or even moderately good "view" from the necessarily large fuselage.

Advantages and Disadvantages of Type "C."

Machines designed on lines constituting a radical departure from precedence in design.

Successful machines falling under this heading are at present very limited in number and for the purpose of this review may be taken as being represented by the "Junker," Fokker (Limousine) and Siemans-Schuckert (new type) designs only, of which the Junker is the parent conception.

The "Junker" design would appear to be the only German machine which is based on fundamentally sound and scientific principles. The realisation of the design presents many unusual features, which although generally known are as a rule assessed as eccentricities rather than appreciated at their true significance.

Briefly, the "Junker" firm have aimed at the suppression of all "passive head resistance," and with this as a key to the general design have to outward appearances achieved a brilliant success, the result of which may perhaps be expected to lead to hitherto unhoped for success in the development of giant aircraft. This machine is moreover entirely constructed of metal, and represents the only existing machine which can justifiably be called of "all-metal" construction.

It is therefore proposed to examine more minutely the general basic features of this design.

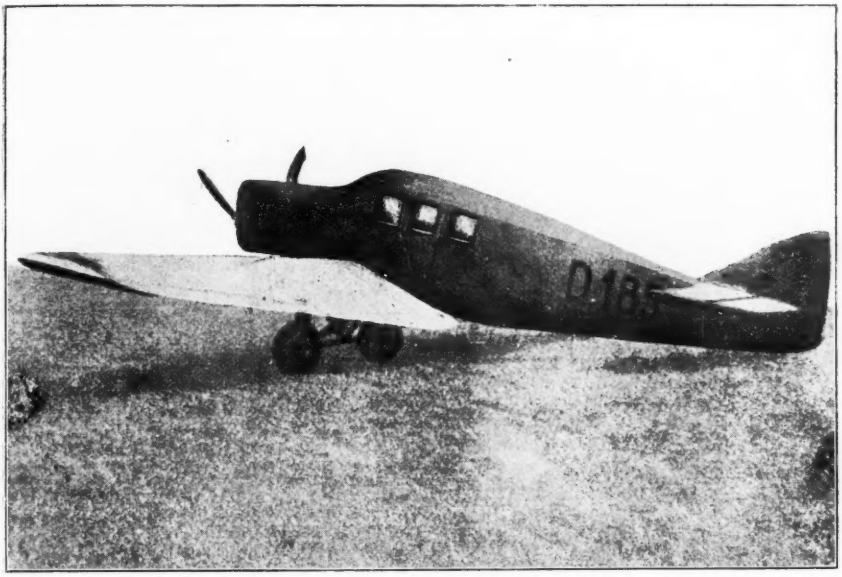
Reference to the photograph, Fig. 3, will at once impress the observer with the absence of struts, stays, king-posts, and other exposed accessories; in a word with the suppression of "parasite" and passive resistances. Further, the machine is of monoplane design, but in other respects, at first glance, similar to the ordinary and familiar designs of the past.

The absence of struts and stays to stiffen the wing spars at once raises a doubt as to the strength and factor of safety of such machines, or in other words

as to whether the wing spars are sufficiently strong in their capacity as cantilever beams to support the weight of the fuselage, engine, crew, etc., in the centre. The "Junker" firm have, however, so arranged the machine that only the bare necessities (consisting of the motor, crew and fuselage) are actually supported in the *centre* of the spars—all other weights, such as *fuel*, spares, tools, etc., are carried inside the wings, and consequently do not to the same extent affect the bending load on the main spares. So that the design in so far as the distribution of motor and fuel weight is concerned reverses the arrangement which charac-

FIG. 3.

A Type "C" machine.



An example of a German Type "C" machine, note the absence of struts, stays, etc.

terises Type "A" (with motors in the wings and fuel, etc., in the fuselage), but retains the advantage of distribution in weight, while at the same time effecting a reduction in head resistance. The importance of this compromise cannot be over estimated, and will again be referred to. In the immediate wake of the successful attempt to reduce head resistance we must now remark on the advantages in regard to the reduction in horse-power which this achievement allows of. The reduction in necessary horse-power indicates a further field of advantage in that the weight of the power plant, and more important still, the weight of the *fuel*, is reduced, which in turn results in a decrease in structure weight. To sum up then, the underlying principles adopted in the design allow of the use of a smaller machine than would at first sight appear possible; or conversely, permit of the carrying of a relatively high useful load (on a given total weight) by reason of the small horse-power required.

So far the advantages of the principles of this design are clearly apparent and the only points in doubt are, firstly, the strength of the cantilever spars, and

secondly, the possibility of the necessarily thick wing section being aerodynamically inefficient. As regards the first point, it should be observed in the absence of other more definite proof that " Junker " machines were built during the war to Government standard specifications and tested accordingly. (Factor of safety of 5.0 is allowed for in the design, which judged by Entente standards is low, but represents the normal German practice for its type.) As regards the efficiency of the thick wing section there may reasonably be some room for doubt when compared as an aerofoil with an ordinary " thin " section, but it must not be forgotten that the adoption of a thick wing section allows of the suppression off all struts and stays, and indeed this is in the case of the " Junker " the reason for its adoption. Add to this the actual and very remarkable performance of the latest " Junker " design and any doubt as to the *practical* efficiency of the " thick " wing must be discarded.

It may be well at this point to mention in passing, the adoption in the " Junker " of metal covered wings. This feature has no connection, as has sometimes been supposed, with the shortage of aeroplane fabric in Germany, but is employed firstly because metal sheet is far more durable than fabric (it retains its curve or section much better), and allows of a great saving of time during construction owing to the constantly changing wing section employed, and secondly, as additional strengthening for the wings themselves, the use of corrugated plates being naturally resorted to on account of " local rigidity."

We now come to the disadvantages of this type of design, and these in the light of present experience would appear to be of a practical rather than of a theoretical nature, for which it is necessary to rely on the statements of Junker pilots. Opinions as to the characteristics of the special wing construction seem to agree without exception as to the strength of the wings when in the air; fear is however expressed of the wings, owing to their too great " rigidity," breaking off " downwards " as the result of a bad landing. This point is one, perhaps, which should receive considerable attention, but is nevertheless largely capable of correction if specially designed and unusually flexible landing carriages are employed.

The next point is that of controllability—pilots stating that as a rule the machine is " difficult to land "—but this defect is apparently more visionary than real.

These remarks in relation to the strength and flying qualities of the Junker cantilever design, are inserted solely with a view to dispersing the scepticism with which many minds regard such departures from previous practice. At the same time it must be remembered that for our purpose we regard the Junker as a *type* only and not as an individual machine.

It should, however, not be forgotten that the realisation of metal construction, cantilever wings, has not been the result of haphazard chance, but represents an accumulation of painstaking research work in metallurgy and engineering science. The solution of this unique construction has been both slow and costly, moreover, it can safely be assumed that the full penalty for this development has not yet been paid.

So far the discussion has been confined to the Junker as it at present exists. It is the development of the machine which however is of peculiar interest, in so far as if the arguments in favour of the design are as well founded as they appear to be, and the practical disadvantages of the existing type overcome; then the constructional difficulties in the building of an enlarged machine of the general design would be very much less than in existing circumstances (with a comparatively small machine). Moreover, an increase in size, either with or without two or more engines, would not appreciably affect head resistance, since engines, gears, shafts, etc., could all be enclosed in the fuselage or within the wings themselves.

In no other type of design is it possible to trace such a set of circumstances in themselves so advantageous to the enlargement of aircraft, and at the same time so open to that compromise which is the essence of every successful machine.

It should be observed also that in the case of cantilever wing aeroplanes, the placing of the motors in the wings has also, as in the case of Type " A " machines, certain advantages in so far as the design and arrangement of the landing carriage is concerned—a point of no small significance in the case under consideration, when the question of bending load or the main spars is all important.

NOTE.—So far the foregoing observations on the three separate lines of development in giant aircraft (Types A, B and C) have been of a general nature, and as such applicable to both aeroplanes and seaplanes, and thus far the development of the giant aeroplane and seaplane has run a parallel course, with the same basic considerations in each case. Indeed, this must naturally be the case when one considers that the reason and necessity for increasing the size of aeroplanes is solely that of obtaining a greater useful load, whether as in the case of the seaplane in order to carry more fuel or as in the case of the aeroplane to carry a greater bomb load or armament. And since the fundamental considerations are the same for both the aeroplane and the seaplane we shall, if necessary, make use of the experience gained with both types if this should tend to assist our inquiry, which for the present is however concerned more closely with the aeroplane.

Summary of the General Features of A, B and C Types of Giant Aircraft.

In order to, as far as possible, arrive at a conclusion which will indicate the lines along which real progress and practical efficiency are to be obtained, the general features of the three " types " of aircraft (as distinct from secondary or individual peculiarities) must be considered from a definite standpoint which will embrace the fundamental principles at stake, general efficiency, and the actual application of theory to practical design.

In order, therefore, to crystallise the arguments for and against the various " types " of giant aircraft, the following table of " advantages " and " disadvantages " has been prepared, and shows at a glance the leading features attending the adoption of the " type " design for each of the three separate classes.

	ADVANTAGES.	DISADVANTAGES.
Type A.	1. Simplicity of design. 2. Simplicity of construction. 3. Cheapness of construction. 4. No experimental work required.	1. Excessive head resistance. 2. Poor performance and general inefficiency.
Type B.	1. Increased efficiency. 2. Reliability and accessibility.	1. Greater structure weight. 2. Expense in provision of gearing. 3. Limitation in size due to growth of structure weight.
Type C.	1. Efficiency. 2. Durability of structure and " life " of the aeroplane. 3. Low running costs.	1. Expense of construction and experiment. 2. Difficulties of construction.

From the table, which is representative within each classification of the general features of all the German machines under consideration, it is possible from super-

ficial considerations *only*, and in conjunction with the foregoing arguments, to say that:—

As regards Type " A " machines—

(1) The prevalence of this type is due mainly to military war requirements, and the possibility of rapid " production " due to constructional simplicity.

(2) That for commercial purposes giant machines of this type will be inefficient and unsatisfactory.

(3) That the ultimate abandonment of the type is certain.

As regards Type " B " machines—

(1) That improved efficiency and greater " reliability " as compared with Class " A " machines will give this type a temporary " commercial " vogue.

(2) That the expense of gearing, etc., for the special arrangement of power transmission, and the increasing difficulty of maintaining efficiency in very large examples of this type due to constructional limitations will eventually lead to its abandonment.

As regards Type " C " machines—

(1) Although in Germany represented by only three machines, that the efficiency, durability and general soundness of the underlying principles of its conception, indicate clearly a new and promising line of advance towards satisfactory giant machines.

(2) That the vast amount of technical skill, elaborate experiments and expense, which are necessary for the building up of this type, will render its development under normal conditions very slow.

We shall see later how accessory circumstances and minor considerations affect or modify these initial conclusions.

In the meantime we will proceed to review the characteristics of some of the *minor* features peculiar to each " type " or class of machine, in order that before coming to any definite conclusion we may see more clearly the balance of compromise observable in German machines as between the desire that inspires conception and the realisation in practice of each " type " design.

NOTE.—In the following chapter on " Minor features of German Giant Aircraft " we shall omit consideration of the details of giant seaplanes, but shall reserve the right to refer to them again, if necessary, in our conclusions and deductions.

III

MINOR FEATURES OF GERMAN GIANT AIRCRAFT.

CONTENTS.

1. Construction.

Section (*a*) Wings—arrangements, construction and design.
,, (*b*) Fuselage or body.
,, (*c*) Landing carriage (aeroplanes).
,, (*d*) Control surfaces—ailerons, rudders and elevators.
,, (*e*) Note on the factors of safety.
,, (*f*) " Limits " of construction.

2. **Performance.**

Section (*a*) German giant aircraft performances.
,, (*b*) Range and duration.
,, (*c*) Controllability and stability, with note on the possible advantages of "thick" wing sections.

3. **Military Features.**

Section (*a*) Crew and defence armament.
,, (*b*) Bomb armament.
,, (*c*) "Maintenance."

4. **Power Plant and Installation.**

Section (*a*) Arrangement.
,, (*b*) Gearing, gear drives, etc.
,, (*c*) Fuel storage.
,, (*d*) "Forced induction."

(1) CONSTRUCTION. SECTION (*a*) WINGS.

Choice of Wing Section.

The German designer has probably a very much larger choice of wing sections whose characteristics are definitely established than in the case of British or French designers. Reference to the "Technische Bericht" (Charlottenburg) will show this, and in addition it should be remembered that there are a number of other well equipped laboratories which undertake aeronautical research and test work. The choice of a wing section then is unusually large, and in consequence giant machines exhibit a wide range of differences. In general, however, the sections adopted are relatively heavily cambered, and within the category of "high-lift" wings. An extreme case is that of the "Junker" with its cantilever spars and heavy camber, but with the wing section becoming naturally less deep towards the wing tips. The Junker wing, however, deserves special consideration and should be treated separately.

Since, however, the choice of wing sections is a matter largely dependent on the individual circumstances of each particular case, it is not necessary to include an examination of this matter in our survey. As regards the wing sections it remains only to add that even in the case of the largest giant machines there is no room between the surfaces of the wing—except in the special case of cantilever wings—to accommodate fuel or any other substance.

Wing Surfaces of "Type A and B" Machines.

All the "Type A" machines which we have had under review are equipped with "thin" section wings, constructed entirely of wood. The wing spars (partly owing to the shortage of wood) are in most cases of composite construction and usually of simple "box" form or section. Attempts to build spars on the "Zeppelin girder" system from short lengths of wood do not appear to have been very successful, though this method of construction has been tried.

A certain amount of metal work is to be found in the tail planes of many of the giant machines, but generally speaking, the construction of the wings and even the inter-plane struts is of wood.

The wing bracing of Types A and B is usually carried out with stranded cable, and the lift wires are as a rule not duplicated, though cross bracing is fitted between the strut bays. Bracing cables as a rule are carried right round the main spars and spliced, so as to form a loop. This form of construction, which

is perhaps somewhat crude, has the effect of simplifying considerably the main spar metal fittings.

The wings of " Type A " giant machines seem to give very little trouble in spite of their comparatively small factor of safety. On the other hand, the fact that the main weights (due to the motors being fitted in the wings) are widely distributed is a great advantage so far as the construction of the wings themselves is concerned.

Wing Surfaces and Structure of " Type B " Machines.

The same general remarks are applicable in regard to the structure of the wings as in the case of " Type A " machines. In this case, however, owing to the concentration of weight in the centre of the machine, a great deal of difficulty has been experienced with the wing structures. In at least one instance a large " Type B " machine had to be abandoned on account of lack of rigidity in the wings. (Factor of safety 4.0.) This is a point of very great importance, and already indicates the fact that in point of size the existing " Type B " has reached—if not passed—the practical limits of construction. It is interesting to note that in this case practice coincides exactly with theory. Obviously, therefore, we cannot expect to see a further development of this type of machine without some radical change in weight distribution, such as will again permit of the wing-structure being made sufficiently robust for practical purposes.

Wings and Wing-structure of " Type C " Machines.

The construction of the cantilever wing of Prof. Junkers is in almost all respects entirely different from the wood-and-fabric wing construction of the " Types A and B." No wood is employed. In place of the old standard arrangement of two main wooden spars, there are nine metal tube spars. No ribs are used except at the loading edge of the plane, and the wing surfaces are of corrugated duralumin sheet. The detail description of this wing is, however, a matter for separate study. We require only to note that the durability of the all-metal wing is infinitely superior to its fabric-covered predecessors, that the construction is simple, and that the wings have given good results in practice.

Being very deep at the roots, there is ample room inside the wing surface for the storage of petrol, spare parts, etc. It is possible, in fact, with this type of wing to arrange the weight distribution in almost any manner desired, by the simple process of altering the fuel-tank position inside the wings. It is as well to repeat that in this case the weight distribution can be arranged as required, without in any way affecting the head resistance of the machine. In the case of very large machines, it is impossible to over-estimate the importance of this fact.

General Remarks on Wing Structure of German Giant Machines.

It may be said that so far as the wings of " Type A and B " machines are concerned, German practice differs but little, except in minor details, from the usual practice in Entente countries. The main considerations have in each case been the same, and it remains only to say that the German products are somewhat crude and ill-finished when compared to Entente standards, but at the same time this is clearly traceable to the serious shortage of all raw materials.

The same cannot be said of the German all-metal cantilever wings. These are at present in a class apart, and represent an achievement in engineering science to which there is no parallel in Entente countries. Moreover, it would not be easy to imitate or improve upon the existing German model without a considerable amount of expenditure in experimental work and careful research into the special properties of aluminium alloys.

It might be as well to remark that the Junkers firm have made great efforts to employ steel in the construction of their cantilever wings, but without success; the principal disadvantages being due to lack of local rigidity in the lighter parts, and also to rapid deterioration from exposure to normal weather conditions. Obviously, however, the disadvantages attending the employment of steel tend to diminish as the size of the machine—and in consequence the size of the individual parts—increases.

Section *(b)*, Fuselage or Body (Giant Machines).

The variation in the methods of construction employed for the bodies of German Giant machines is so large as to make it impossible to distinguish any one particularly satisfactory or exceptional type of design.

If we include the Junker all-metal fuselage, we have, in addition to this example, fuselages constructed of: (*a*) Wood veneer, (*b*) wood and wire bracing, (*c*) composite steel and wood with wire bracing, and (*d*) steel tube. It is difficult to say which of these various designs is the best or most promising. It seems, however, that the very large wood veneer fuselages are extremely heavy, and it is doubtful if they can be successfully employed for very big machines.

As regards the **all-metal** fuselage of the Junker, it is at present impossible to say whether or not this form of construction would be satisfactory in very large examples. Actually there is reason to suppose that the special form of construction employed in the present machine is not over-robust, but it is possible that this defect is due to the difficulty of obtaining (in Germany) reliable duralumin.

There is a tendency in the larger German Giants to reduce the length of the fuselage, and to substitute a large tail fin instead, with the object of cutting down weight. This practice is a questionable one, and usually results in difficulty with the control surfaces and tail fin. This particular tendency is, however, more marked in the large " Type B " machines, where the weight of the fuselage and its contents are in any case higher than is desirable. As regards the steel-constructed fuselages, we note an absence of any special fittings at the tube joints. German aeroplane constructors apparently have a good deal of faith in the ordinary process of acetylene-welding, although as a general rule the workmanship displayed by the welded joints is not of a very high order. The usual system of welded steel construction is also ill-adapted to repairs or replacements.

In general the construction of the bodies for giant aeroplanes is simple and cheap, the workmanship is indifferent, and the structural design of no particular merit.

Section *(c)*, Landing Carriages.

We have in the introduction remarked that German giant machines were primarily designed for strategic purposes. They were not, therefore, expected to work from improvised aerodromes such as must necessarily be used when close up to the Front. We find, therefore, that the landing carriages of the German giant machines are as a rule of very indifferent design compared with Entente standards, and quite incapable of negotiating bad ground.

The wheels are, generally speaking, absurdly small and somewhat numerous. In the majority of cases, due to the small diameter of the wheels, arrangements are made to allow of additional wheels being fitted to the same axles for use in wet weather and on soft ground. Even so, in many cases designers fit auxiliary front wheels on the front of the fuselage, in order to guard against the likelihood of their machines " turning over " forwards when the wheels encounter obstacles on soft ground. German giant landing carriages are therefore, as a rule, cumber-

some and have a high relative head resistance, due to the auxiliary wheels in front.

It should be remarked that the small size of the main wheels may have been to a large extent due to the shortage of pneumatic tyres and the impossibility of obtaining large tyres suitable for big diameter aeroplane wheels. At all events, from a practical point of view, German giant landing carriages are inferior to those of the corresponding Entente machines.

There is nothing remarkable about the shock-absorbing devices employed or the general design of landing carriage struts or framework.

The landing carriage of the newest Junker machine (" Type C ") is remarkable in that while the design is that of the simple and familiar V type, the arrangement differs from standard practice in that both the V struts are themselves shock-absorbers. This arrangement, which has been adopted on account of the long unsupported length of the wings, allows the axle to travel both upwards and backwards when negotiating rough ground.

Note.—During the last two years of the war, only machines actually employed at the Front were fitted with pneumatic tyres. Training and practice machines of all types were equipped with wooden-rimmed wheels.

Section (*d*), **Control Surfaces.**

The control surfaces of German giant machines are almost always " balanced," sometimes by the simple addition of a small portion of control surface which projects forward and in front of the hinge axis, and sometimes by the addition of a small auxiliary surface.

The newest giants are fitted with adjustable " fixed " tail planes in imitation of the Entente machines.

All controls are as a rule spring compensated and so fitted as to be readily adjustable from the pilot's seat. These fittings are of a simple nature and contain nothing new or novel to ordinary standard practice.

It is interesting to observe that in nearly all cases the elevators are built on a continuous spar or tube in such a way, therefore, that the right and left hand portions of the elevator cannot (when the control wires become slack) move independently. This method of construction, although slightly heavier than the more usual system of " split " elevators, has the great advantage that while it re-duplicates the control wiring it also serves to damp out torsional vibration in the fuselage and to prevent its taking place.

While it is not possible, without actual personal experience, to make any statement as to the efficiency of the " giant controls," it is a fact that pilots of the large " Type A " machines rely more on their engine throttle controls than on the ailerons when flying in bad weather. At the same time the actual area of the German giant control surfaces is as a rule proportionately very much less than in Entente countries.

The proportional " part weights " of German giant control surfaces and control gear are, generally speaking, a good deal heavier than might be anticipated. This is to some extent due to the fact that German designers have a tendency to build short fuselages in order to save weight in the fuselage itself. This feature naturally increases considerably the weight of the control surface, tail fin, etc., which have to be made correspondingly larger.

Section (*e*), **Note on " Factor of Safety."**

During the war, and therefore applicable to all German machines at present

under consideration, the following were the official "factors of safety" according to Government specifications:—

E and D Types ...	...	Factor of 5.0
C and G ,, ...	...	,, 4·5
R ,, ...	...	,, 4.0 (giant machines)

It is safe to assume that these factors were rigorously enforced, and indeed in the case of German "fighters" the specified factors must have been as a rule very considerably exceeded.

So far as can be ascertained, few if any cases of "failure" in the air occurred with giant or "R" machines. In connection with this it must be again remarked that the control surfaces, and particularly the elevator surfaces, in German giant machines are small. It is not possible to determine, however, whether or not this is due to deliberate intention with a view to preventing pilots from imposing undue strains on their machines from too violent use of the elevator. With a reduced factor of safety this point is of considerable importance, but in any case in the light of German experience a factor of safety of 4.0 in the case of giant machines, appears to be quite sufficient for all normal purposes.

Section (*f*), Limits of Construction.

The following table gives some indication of the composition of the total weight in giant machines of "Type A" and "Type B." It shows the percentage weights of the "glider" (that is to say, the aeroplane structure), the "power plant," including propeller gears and transmission, and also the "load" and "fuel."

PERCENTAGE WEIGHTS IN RELATION TO TOTAL WEIGHT, GERMAN "GIANT" MACHINES.

"Type."	No. of Motors.	H.P.	Glider Wt. %	Power Plant %	Useful Load %	Load %	Fuel %	Total Wt. in kg.
"Type A"	3 motors	735	45·5	19.6	34·9	23·9	11.0	10,203
"Type A"	4 motors	1072	43.2	23.8	33.0	15·7	17·3	11,460
"Type A"	4 motors	1072	39·5	27.1	33·4	17·3	16.1	11,693
Mean values ...	...		44.1	23·5	33.8	18.9	14.8	11,119
"Type B"	6 motors	1228	41.3	27.6	31.1	14.6	16.5	12,953
"Type B"	6 motors	1228	40.1	27.2	32.7	16.3	16.4	13,035
Mean values ...	...		40.7	27·4	31·9	15·4	16.4	12,994

Any discussion of these figures (whose accuracy can be relied upon) would be controversial, and for our purpose of no great value. We require to note, however, that the glider weight of the "Type B" machines is less than in the case of the "Type A" machines. This fact is not easily accounted for. It however must be remarked that the "Type B" machines are of more recent construction and that their total weight is greater.

The additional weight of the power plant of the "Type B" machines is clearly apparent (the figures include the propellers, gears and shafting).

In all other particulars it will be observed that the "Type B" weight percentages are inferior to those of "Type A" design. It remains to be seen how these circumstances are either reflected or compensated for in "performance" results.

As regards the proportion of useful load and fuel in existing giant machines of both types, it is necessary to insist that these are considerably more satisfactory than has been imputed by aeronautical theorists. In any case it is quite clear that as regards weight proportions, the giant machines in question are far from any "limits" which theoretical consideration may suggest. This circumstance is extremely important, particularly when it is remembered that the materials employed are for the most part inferior, and that the designers were heavily handicapped by the low power of the individual motor units.

(To be continued.)

CORRESPONDENCE.

To the Editor of the AËRONAUTICAL JOURNAL.

DEAR SIR,—I have read with great interest Mr. Thomson's comments on my paper on the flying of twin-engined aeroplanes. Among other things he refers to the effect on the fins of twin-engined aeroplanes when the airscrews revolve inwards.

With the standard Handley Page o/400 and Vickers Vimy aeroplanes, in which the airscrews revolve the same way, there is a definite turning tendency noticeable. I believe that some of the early Handley Page o/400's had inward turning airscrews, and though I have no first-hand experience, I have been told by a pilot who has flown one that, as would be expected, there was no turning tendency. So far as I know, the Vimy was designed after Messrs. Rolls-Royce had standardised the sense of rotation of their engine.

Mr. Thomson states that a Vimy proved capable of flying on the port motor (an inward turning engine), but failed to fly level on the starboard one, owing to the nose having to be put down and a greater speed attained to overcome the turning tendency.

As far as my knowledge of the Vickers Vimy goes, the port engine turns outwards. If then "starboard" be substituted for "port," I have not noticed this to any extent when flying a Vimy, although I have not measured the rudder forces when flying on the starboard and port engines with the standard fins.

I think it may be for this reason. Take the case of a standard Vimy, flying on the starboard engine which turns inwards, the port engine being cut out. The starboard engine brings into play a couple tending to turn the aeroplane to port; the rudder is put over to starboard to counteract this, but at the same time produces an unbalanced lateral force, which, if the wings are to be held level, can only be balanced by the aeroplane sideslipping to port. The slipstream of the starboard engine, which would normally be exerting a force on the fin tending to counteract the turning tendency, is diverted by the sideslip; thus the fin is not affected, and the value of the inward rotating slipstream is practically lost. If this is so, the case for inward turning airscrews is considerably weakened.

I am afraid I have no specific information on the control at low speeds of the early aeroplanes built at Farnborough, but general experience would seem to suggest that with the present form of control surfaces, abnormally good control at low speeds is only to be had by making the control at high speeds excessively heavy.

Yours faithfully,

R. M. HILL.

Experimental Section,
Royal Aircraft Establishment,
S. Farnborough.

REVIEWS.

A Treatise on Airscrews. Whyrill E. Park, A.R.C.Sc.

This work is frankly empirical and aims at showing how to design a propeller for a given purpose rather than examining how a propeller functions. A theoretical or mathematical treatise may be judged by itself, but the true value of an empirical work must depend on the experience and authority of the writer. We understand Mr. Park was the designer for Lang Propellers Ltd. towards the end of the war, and in so far as this work embodies the experience of that firm, the book should within limits be a useful one for designers.

It is well written and sound where the author deals with the drawing office design of a propeller using the simple blade element theory, and in the section dealing with construction. Elsewhere, in the treatment of the effect of obstructions, tandem propellers, variable pitch propellers and all the important side issues, the treatment is weak and in many cases amounts to little more than a mention. The absence of a chapter dealing in detail with the effect of gearing is an omission.

One serious error we must point out. The author apparently has not grasped the fundamental conceptions underlying the inflow theory. He has confused the term "slipstream" with the unfortunate term "slip" used in some early reports of the Advisory Committee, a term very similar in meaning to that used in marine engineering.

The slipstream velocity he states to be constant and equal to the velocity of translation at no thrust. His inflow is therefore taken as one half the difference between the no-thrust velocity and the actual aircraft velocity. Thus, in the example which he worked out to compare the results given by the simple theory and what he takes as the inflow theory, he obtains an average *inflow* of about 39 feet per second.

The difference in horse-power absorbed and efficiency as between the two methods, says the author, is "alarming." We agree, but the alarming result is due not to the inflow theory but to the author's misunderstanding. Worked out on the inflow theory as commonly accepted and understood, the inflow velocity in this particular example should be about 9-10 feet per second. This mistake carries through the book and vitiates the already weak treatment of tandem propellers.

It is also somewhat disturbing to be told on page 39 that the slipstream $V_1 + v$ is constant and on page 46 that inflow velocity is directly proportional to the translational velocity.

Had the book been limited to construction strength and to the simple theory of design we could have recommended it. As it is we can only recommend it to those who have sufficient experience with propeller design and theories to be able to distinguish the good from the bad and to apprise the value of the empirical rules given.